IRVING'S CATECHISM OF ASTRONOMY

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Rewritten by

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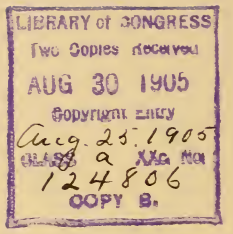

PREFACE.

The object of this CATECHISM OF ASTRONOMY is to present the fundamental facts and truths of astronomy in a clear and succinct manner. The catechetical method has been adhered to, as being best suited for the yet immature minds of children in the advanced grades of the primary school, for whom this catechism is mainly intended. Possibly, the little volume may also prove useful as a convenient reference book to look up the more common data and doctrines of astronomical science.

The changing of night into day by strong artificial illumination, especially in the towns and cities, has made the starry firmament a strange object to many, and it is safe to say, that, comparatively, only a few have more than a vague idea of the diurnal motion of the stars. It seems, therefore, advisable to direct the attention of the young to the splendor and the beauty of the star-spangled vault of heaven and to tell them that in the science of astronomy human reason triumphantly asserts its dominion over space and matter. For, relying on the universality of the divinely constituted laws of nature, the astronomer weighs distant systems as on a scale, he predicts their future positions and configurations, and, aye, though trillions of miles away, he analyzes their composition and determines the elements of which they are composed.

In our commercial age where the unselfish, the good, and the noble are too often lost sight of in the pursuit of selfish and utilitarian ideals a little book may well be in place which directs the gaze to the heavens of which the Psalmist sings: "The heavens shew forth the glory of God and the firmament declareth the work of his hands." (Ps. XVIII, 2, 3.)

St. John's University,
Collegeville, Minn., April, 1905.

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Catechism of Astronomy.

INTRODUCTION.

Laws of Motion, Gravitation, Telescope and Spectroscope.

Motion.

Q. 1. What is motion?

A. Motion is a continuous and successive change of position.

Q. 2. What is the simplest kind of motion?

A. The simplest kind of motion is motion along a straight line with unchanging speed.

Q. 3. What produces, changes or destroys motion in a body?

A. A force only, acting on a body, can produce, change, or destroy motion in that body?

Q. 4. If a body is at rest and no force acts on it, how will it behave?

A. It will remain at rest forever.

Q. 5. If a body is in motion and no force acts on it, how will it behave?

A. It will move on forever in a straight line and with constant speed.

Q. 6. When a force acts on a body in the line of motion, how will it be affected?

A. Its speed only will change.

Q. 7. When a force acts continuously on a body across the line of motion, *i. e.*, at right angles with it, how will it be affected?

A. The speed of the body will remain unchanged but the direction will continuously change so that the body moves in a circular path.

Q. 8. When a force acts on a body at an angle with the line of motion, how will it be affected?

A. In general, both the speed and the direction of motion will change.

Q. 9. What is real motion of a body?

A. Real motion of a body is actual change of place of that body.

Q. 10. What is apparent motion of a body?

A. Apparent motion of a body is a seeming change of place of that body. In reality, the body is at rest and the observer moves in a direction just opposite to the apparent motion of the body.

Q. 11. Can you give an example of this motion?

A. When riding in a train, the trees, houses and

other objects near by seem to move in a contrary direction to that of the train.

Apparent Motions of the Planets—Direct, Retrograde and Stationary.

Q. 12. What is meant by the direct motion of a planet?

A. The motion of a planet is direct when its motion among the stars is eastward.

Q. 13. When does this take place?

A. It takes place, when the planet is farthest from the earth. (Fig. 1, from P to P^{1}.)

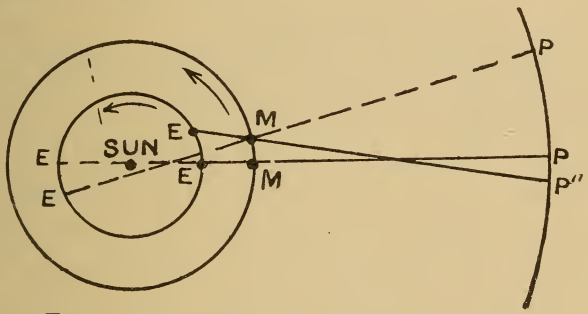

FIG. 1. APPARENT MOTION OF A PLANET.
E represents the Earth, M a planet, and P, P1, P11, the apparent positions of this planet among the stars.

Q. 14. What is the retrograde motion of a planet?

A. A planet has retrograde motion when its apparent motion among the stars is westward.

Q. 15. When does a planet retrograde?

A. It retrogrades when it is nearest to the earth? (Fig. 1, from P to P^{11}.)

Q. 16. When is a planet said to be stationary?

A. A planet is said to be stationary when its

position among the stars remains seemingly fixed for some time.

Q. 17. When does this occur?

A. It occurs between the direct and retrograde motions of the planet.

Q. 18. What is the cause of these appearances?

A. The cause of these appearances is the combined motions of the earth and of the planet in their orbits around the sun.

Gravitation.

Q. 19. What is gravitation?

A. Gravitation is that property common to all bodies whereby they attract each other.

Q. 20. What is the law of gravitation?

A. Every particle of matter in the universe attracts every other particle with a force which acts along the line joining any two particles considered, and whose magnitude is proportionate directly to the product of the masses, and inversely to the square of the distance between them.

Q. 21. Who is the discoverer of this law?

A. The great Sir Isaac Newton discovered this law toward the end of the seventeenth century.

Q. 22. Is this law of any importance in astronomy?

A. The law of gravitation is of the greatest importance in astronomy, for by it the motions of the heavenly bodies are controlled and their shapes determined.

The Telescope.

Q. 23. What is a telescope?

A. A telescope is an optical instrument which magnifies the images of distant objects, or if the images be simply points of light, as those of the fixed stars, it increases their brilliancy.

Q. 24. How many kinds of telescopes are there?

A. There are two kinds of telescopes, namely, the refractor and the reflector.

Q. 25. Of what does the refractor in principle consist?

A. The refractor consists in principle of a light-gathering lens or system of lenses, called the object-glass, which makes the light-rays convergent, and of a second lens or system of lenses, called the eye-piece, which magnifies the image produced by the first.

Q. 26. What are the essential parts of a reflector?

A. The essential parts of a reflector are a concave mirror which, after reflection, brings the light-rays, coming from a distant object, to a focus, and an eye-piece, as in the refractor.

Q. 27. What other classification may be made of telescopes?

A. Telescopes are also classified as visual when the image is viewed with the eye, and as photographic, when the image is received on a photographic plate.

Q. 28. Are telescopes important instruments to astronomy?

A. Telescopes are of the greatest importance to

astronomy, for they reveal a great many things which would otherwise remain hidden, *e. g.*, the surface markings of the planets and millions of stars.

The Spectroscope.

Q. 29. What is a spectroscope?

A. A spectroscope is an optical instrument for forming and observing the spectra of bodies.

Q. 30. What is a spectrum?

A. A spectrum is a series of images arranged according to wave-lengths.

Q. 31. Have the elements spectra of their own?

A. Yes, every element has a spectrum of its own.

Q. 32. When a body is examined with a spectroscope, what conclusions may be drawn?

A. The spectra show what elements are present in the body.

Q. 33. How is the spectroscope used in astronomy?

A. By examining with the spectroscope the light coming from the sun or a star, we learn what elements are present in them?

Q. 34. What other important thing does the spectroscope do?

A. By the shifting of the series of images (generally they are lines or bands) in the spectrum, the spectroscope tells us how fast a star is approaching the earth or receding from it.

CHAPTER I.

ASTRONOMY.

Q. 1. What is astronomy?

A. Astronomy is the science which treats of the heavenly bodies, their motions, distances, magnitudes, physical condition and chemical composition.

Q. 2. Has astronomy been subdivided?

A. Yes, astronomy has a number of subdivisions, such as descriptive, practical, theoretical, mechanical, spherical, and physical astronomy.

Q. 3. On what division of astronomy is this catechism mostly based?

A. This catechism is mostly based on descriptive astronomy which is nothing but a general statement of astronomical principles and facts.

Q. 4. Is astronomy of any practical value?

A. Yes. Geodesy, accurate surveying, navigation and time-service are all based on astronomy.

Q. 5. Has astronomy any other value?

A. Astronomy has very great value as a mental discipline; in fact, it forms an important part of a liberal education nowadays, and in the Middle Ages it was one of the seven liberal arts.

CHAPTER II.

History of Astronomy.

Q. 1. Is astronomy of great antiquity?

A. Astronomy was cultivated by the Chinese, Egyptians, Chaldeans, Greeks and Hindoos, even many centuries before the Christian era.

Q. 2. Who were some of the most celebrated astronomers of antiquity?

A. Pythagoras, Meton, Aristarchus, and Hipparchus were some of the most celebrated astronomers of antiquity.

Q. 3. What did Pythagoras teach?

A. Pythagoras (B. C. 569-470) is said to have taught that there was a central fire in the universe around which the sun, moon, earth, planets and stars revolved.

Q. 4. What did Meton discover?

A. Meton (B. C. 433) discovered the Metonic cycle which consists of 235 synodic months (from new moon to new moon) and is very nearly equal to 19 common years of 365¼ days.

Q. 5. For what was this cycle used?

A. It was used to make the lunar years, according to which the ancient Greeks reckoned, correspond with the solar years; and it is still used in finding the time of Easter.

Q. 6. What did Aristarchus maintain?

A. Aristarchus (B. C. 310-250) was the first to maintain that the earth rotated on its axis and revolved around the sun.

Q. 7. What did Hipparchus do?

A. Hipparchus (B. C. 190-120) "the Father of Astronomy" was the first to make a catalogue of stars.

Q. 8. Who were some of the renowned astronomers of the early Christian era?

A. Ptolemy, Theon and his daughter Hypatia (375-415), and the Arabian astronomer Albategnius (877-929) are the best known astronomers of these times.

Q. 9. What did Ptolemy write?

A. Ptolemy (87-165), wrote a work which became known later by the name of Almagest, wherein he explained his theory of the motions of the heavenly bodies.

Q. 10. Was Ptolemy's theory widely accepted?

A. Ptolemy's theory held full sway for 1400 years.

Q. 11. Which were the salient features of the Ptolemaic system?

A. According to this system the earth was at the center of the universe and did not move; the whole heavens revolved around the earth from east to west in one day; besides, the sun, moon, and planets were supposed to have certain proper motions to account for their apparent motions in the heavens.

Q. 12. What prominent astronomers lived in later centuries?

A. Regiomontanus, Copernicus, Tycho Brahe, Galileo, and Kepler.

Q. 13. Who was Regiomontanus?

A. Regiomontanus (1436-1476), whose real name was John Mueller, became the assistant of the astronomer Purbach, at the age of sixteen; subsequently he calculated and published the places of the planets for many years ahead.

Q. 14. Who was Copernicus?

A. Copernicus (1473-1543), a canon at the cathedral of Frauenburg, is the author of the system which bears his name.

Q. 15. What is the Copernican system?

A. The Copernican system with a few later corrections and additions is the astronomical system which is now universally held and which is known to be the only true system.

Q. 16. What are the main points of the Copernican system?

A. It teaches that the earth rotates on its axis and with the other planets revolves around the sun.

Q. 17. Who was Tycho Brahe?

A. Tycho Brahe (1546-1601), was the best observer of his time; he also devised an astronomical system which, however, was never widely accepted.

Q. 18. Who was the first to use the telescope for astronomy?

A. Galileo (1564-1642), was the first to apply the telescope to astronomical observation.

Q. 19. What did Kepler discover?

A. Kepler (1571-1630) by careful comparison and study of the recorded positions of the planets, especially those made by Tycho Brahe, discovered the three great physical laws which bear his name.

Q. 20. Which is the first of Kepler's Laws?

A. The first law states that the orbit of each planet is an ellipse, with the sun in one of its foci.

Q. 21. Who are some noted astronomers of still later times?

A. Huyghens, Roemer, Newton, and William Herschel.

Q. 22. What is to be noted of Huyghens?

A. Huyghens (1629-1695) proposed the wave-theory of light, and made the first pendulum clock.

Q. 23. Who was Roemer?

A. Roemer, a Dane (1644-1710) is the inventor of the transit instrument; he likewise roughly determined the velocity of light.

Q. 24. What is to be said of Newton?

A. Newton (1642-1727) discovered the law of universal gravitation and wrote a monumental work called the *Principia.*

Q. 25. What did William Herschel do?

A. William Herschel (1732-1832) built several large reflecting telescopes; he also discovered the planet Uranus.

Q. 26. Are there noted astronomers who lived later than the ones just mentioned?

A. Yes, there are a great many noted astronomers who lived after Herschel's time, or who are still living; some of their discoveries will find mention in the different chapters of this catechism.

CHAPTER III.

The Solar System.

Q. 1. Of what does the solar system consist?

A. The solar system consists of the sun and all the bodies that revolve around it.

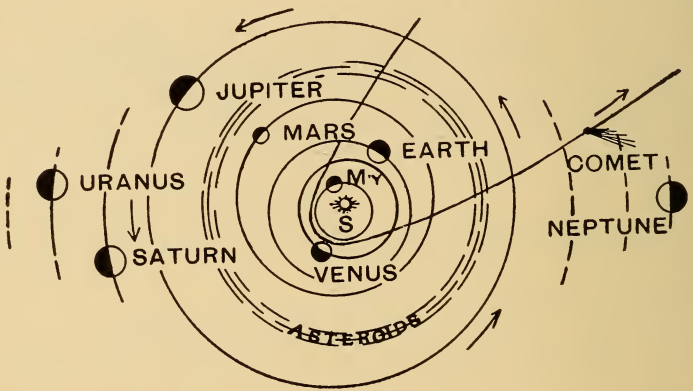

Fig. 2. Solar System.

Q. 2. What bodies are these?

A. They are the planets and their satellites, asteroids, comets and meteorites.

Q. 3. Which are the planets in order of distance from the sun?

A. They are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.

Q. 4. Which are the satellites?

A. The earth has one moon, Mars two, Jupiter seven, Saturn ten, Uranus four, and Neptune one.

Q. 5. Where are the asteroids?

A. The asteroids which are small planet-like bodies have their orbits between those of Mars and Jupiter.

Q. 6. Are all comets permanent members of the solar system?

A. No, most comets are only visitors to our system and most probably will never return to it.

Q. 7. What paths are many meteorites known to follow?

A. Many meteoric swarms are known to follow along the paths of certain comets.

Q. 8. Is the solar system stationary in the universe?

A. No, the sun with all its dependent bodies is moving towards a point in the constellation of Hercules with a velocity estimated at from eleven to fifteen miles a second.

CHAPTER IV.

THE SUN. ⊙

Q. 1. What is the sun?

A. The sun is an intensely hot, self-luminous globe around which the planets circle and from which they receive nearly all their light and heat.

Q. 2. How does the light and heat of the sun reach the planets?

A. They reach it in form of rapid vibration caused by the sun in that substance which is believed to pervade the whole universe and which has been named the luminiferous ether.

Q. 3. How fast does light travel through space?

A. Light travels with a velocity of 186,330 miles a second.

Q. 4. What causes the planets to circle around the sun?

A. It is the sun's attraction.

Q. 5. If the law of gravitation according to which bodies attract each other would suddenly cease to exist, how would the planets then move?

A. They would move off into space along a straight line tangent to the curve at that particular moment and with the speed with which they were then moving. A planet at *P* would move off towards *T*.

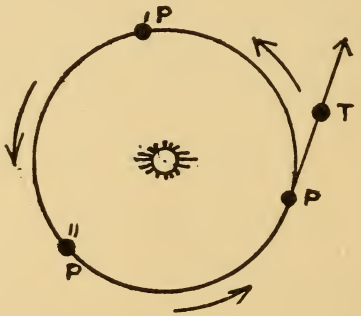

FIG. 3. WERE GRAVITATION TO CEASE.

Q. 6. How far is the sun distant from the earth?

A. The mean distance of the sun from the earth is 92,900,000 miles.

Q. 7. What is the length of the sun's diameter?

A. The sun's diameter is 866,500 miles, which is 109.5 times the diameter of the earth.

Q. 8. How great is the sun's surface?

A. The sun's surface is about 12,000 times as great as the surface of the earth.*

Q. 9. How great is the sun's volume?

A. The sun's volume is about 1,300,000 times that of the earth.†

Q. 10. What is the sun's mass?

A. The sun's mass is very nearly 332,000 times the mass of the earth.

Q. 11. How much would a body, weighing a pound here on earth, weigh on the sun?

A. The body would weigh 27.6 pounds; a person weighing 150 pounds on earth, would weigh 4,140 pounds (over two tons) on the sun.

Q. 12. Does the sun rotate on its axis?

A. Yes, the sun rotates on its axis.

Q. 13. How long does it take the sun to turn around once?

A. At the equator it completes a rotation in 25 days; at solar latitude 20°, in 25.75 days; at solar latitude 40°, in 27 days.

Q. 14. What does this show?

A. It shows that the sun's surface is not solid,

* Surfaces of globes are to each other as the squares of their diameters; in this case, $(109.5)^2 : 1^2$

† Volumes of globes are to each other as the cubes of their diameters; in this case, $(109.5)^3 : 1^3$

otherwise the time of rotation would have to be the same for all latitudes.

Q. 15. Is the interior of the sun solid?

A. Nothing is known of the sun's interior, except by inference, but it seems quite certain that the sun is still in the gaseous state.

Q. 16. How have astronomers named the successive layers of the sun that can be observed?

A. The luminous surface of the sun has been called the photosphere, above this lies the chromosphere from which the prominences rise, and surrounding it all is the corona.

Q. 17. When only, can the corona be seen?

A. The beautiful corona can only be seen at a total eclipse of the sun.

Q. 18. What are sunspots?

A. Sunspots are dark depressions in the photosphere which remain for some time and then disappear.

Q. 19. What is the nature of these spots?

A. The nature of these spots is not yet thoroughly understood; it seems quite probable however, that the spots are caused by cooled vapors falling back to the sun.

Q. 20. What are faculae?

A. Faculae are brilliant white patches on the photosphere, generally seen in the neighborhood of sunspots; they are thought to be heated vapors rising violently from the sun's interior.

Q. 21. Does the spectroscope reveal anything regarding the chemical constituents of the sun?

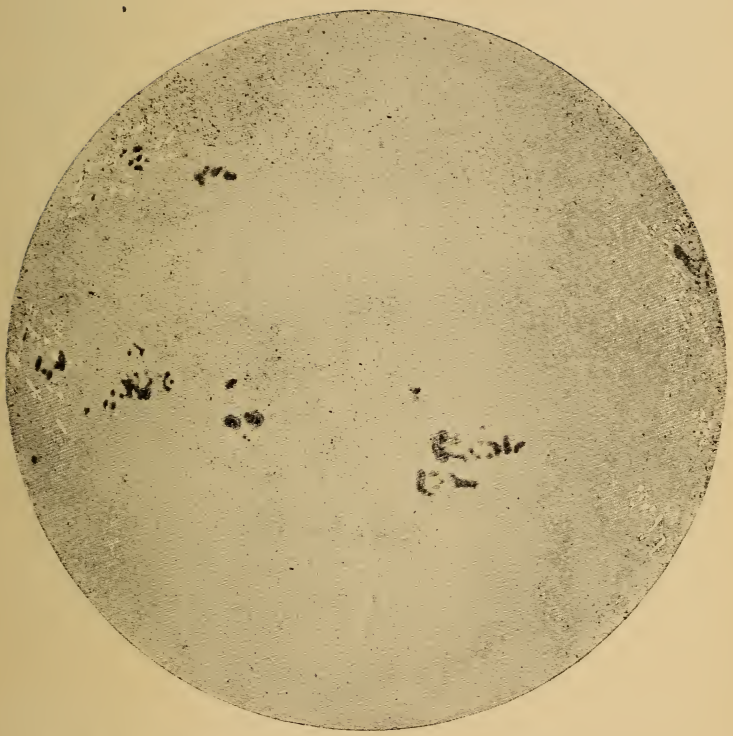

FIG. 4. SUN SPOTS AND FACULAE AT THE TIME OF A SPOT MAXIMUM.

A. Yes, the spectroscope shows that the sun contains many elements which are present in the earth, such as iron, hydrogen, sodium, nickel, carbon, copper, etc.

Q. 22. How hot is the sun?

A. The effective temperature of the sun is very likely somewhere between 10,000° and 20,000° F.

Q. 23. Has the sun any apparent motions?

A. Yes, the sun has two apparent motions; viz: a diurnal motion from east to west and an annual motion around the ecliptic from west to east.

Q. 24. What causes the diurnal motion?

A. The earth's rotation from west to east.

Q. 25. What causes the annual motion?

A. The earth's revolution around the sun.

EXERCISE.—By means of the star-maps determine what constellations are on the meridian, that is, on the north and south line in the sky, about 2 hours after sunset. Write your observation in a memorandum book. After a month make a similar observation. You will notice that those stars which were on the meridian at the first observation are now to the west of it; in other words, the sun has moved towards them. If you repeat these observations for a year, you will find that the sun has made a complete circuit of the heavens. What did really move? the sun, or the earth?

CHAPTER V.

MERCURY. ☿

Q. 1. What planet is nearest to the sun?

A. Mercury is the planet which is nearest to the sun.

Q. 2. How far is it distant from the sun?

A. The mean distance of Mercury is 36,000,000 miles; its actual distance varies from 28,500,000 miles o 43,500,000 miles.

Q. 3. In what time does Mercury revolve around the sun?

A. Mercury completes its revolution around the sun in very nearly 88 days.

Q. 4. How fast does this planet move along in its orbit?

A. When nearest the sun it has a speed of 35 miles a second, which decreases to 23 miles a second when it is at that part of its orbit which is farthest away from the sun.

Q. 5. How much light and heat does Mercury receive from the sun?

A. The heat and light of the sun is 6.7 times more intense at Mercury than at the distance of the earth.

Q. 6. How does the intensity of light and heat vary?

A. The intensity of light and heat varies inversely as the square of the distance from the body emitting the light and heat. (In Fig. 5, the light passing through 1 is spread over 2, which has four times the area of 1.)

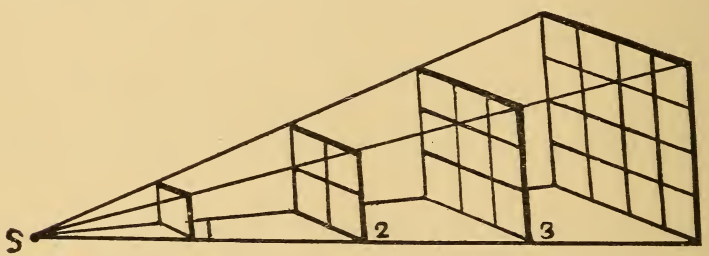

FIG. 5. LIGHT AND RADIANT HEAT VARY INVERSELY AS THE SQUARE OF THE DISTANCE.

Q. 7. How may this be shown for Mercury?

A. If we call the distance of the earth from the sun one, then the distance of Mercury from the sun is expressed by $\frac{36000000}{93000000} = 0.387$. Therefore, light at Mercury: light at earth $= \frac{1}{(0.387)^2} : \frac{1}{1^2}$. Hence, light at Mercury $= \frac{1}{(0.387)^2} \times$ light at earth $= 6.7 \times$ light at earth.

Q. 8. What is the diameter of Mercury?

A. Mercury's diameter is very near 3,000 miles.

Q. 9. How does the surface and volume of this planet compare with that of the earth?

A. Its surface is $\frac{1}{7}$, and its volume $\frac{1}{18.5}$ of the earth's.

Q. 10. Does Mercury rotate on its axis?

A. It seems to be quite certain now that Mercury turns just once on its axis in the time it goes around the sun.

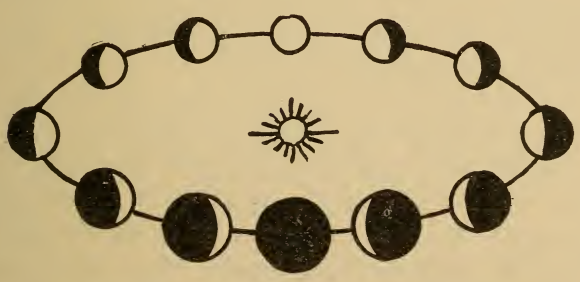

FIG. 6.—PHASES OF MERCURY AND VENUS.

Q. 11. What is the consequence of this?

A. A consequence of this is that one side of Mercury has perpetual night.

Q. 12. How does Mercury appear in a telescope?

A. In a telescope Mercury appears like a little moon, and shows all the phases like our own moon. (See Fig. 6.)

Q. 13. What do the phases of Mercury prove?

A. They prove that the planet shines by the reflected light of the sun.

Q. 14. How does Mercury appear to the naked eye?

A. When Mercury is far enough away from the sun to be seen in the twilight, it appears like a brilliant star of the first magnitude.

Q. 15. What is the apparent motion of this planet?

A. It never moves more than 28° away from the sun; it moves east from the sun and can then be seen in the evening twilight; then it moves westward, passes the sun and swings out west of it, and can then be seen in the morning twilight; thereupon it resumes its eastward motion.

Q. 16. What is a transit of Mercury?

A. Sometimes Mercury passes exactly between the sun and earth; when this takes place Mercury can be seen with a telescope as a dark round spot crossing the disk of the sun. This phenomenon is called a transit.

Q. 17. When will the next three transits occur?

A. They will occur: November 12, 1907, November 6, 1914, and May 7, 1924.

EXERCISE.—From a calendar which gives astronomical data determine at what time an eastern elongation of Mercury occurs. When one occurs in March or April, take that one. Commence looking for a bright star near the western horizon on about the fifth or sixth evening before elongation. By means of the star-maps make sure that what you suppose is Mercury is not a fixed star. If you have a telescope wherewith to view the star, the presence or absence of the phase, a little more than half full, will tell if it is Mercury or not. Observe the planet every clear evening through its elongation. Note also, if possible, its motion among the stars until it is again lost in about fourteen days in the sun's glare. With the telescope the change from gibbous to cresent phase could be observed.

CHAPTER VI.

VENUS. ♀

Q. 1. What is Venus?

A. Venus is the planet whose orbit is between the orbits of Mercury and the earth; it is the most brilliant of all the planets, and is at times easily seen during the day with the naked eye.

Q. 2. How far is Venus distant from the sun?

A. The mean distance of Venus from the sun is 67,200,000 miles; its greatest and least distances do not differ more than 470,000 miles each way from the mean; the orbit, therefore, in which Venus revolves around the sun is almost a circle.

Q. 3. In what time does Venus complete a revolution around the sun?

A. Venus completes a revolution around the sun in 225 days.

Q. 4. How fast does this planet travel in its orbit?

A. It has an orbital velocity of 22 miles a second.

Q. 5. How much light and heat does Venus receive from the sun?

A. Venus receives 1.9 times as much light and heat from the sun per unit area as the earth.

Q. 6. What is the diameter of Venus?

A. Its diameter is 7,700 miles.

Q. 7. What is the surface and volume of this planet?

A. Its surface is 95 per cent of the earth's surface, and its volume is 92 per cent.

Q. 8. What is the rotation period of Venus?

A. Formerly it was believed to be nearly 24 hours; but the observations of Schiaparelli, Lowell, and others, make it very probable that its period of rotation is of the same length as its period of revolution, so that Venus, like Mercury, always keeps the same side turned towards the sun.

Q. 9. How does Venus appear in the telescope?

A. On account of her great brilliancy, Venus is a striking object in the telescope; she shows all the phases of the moon and at certain parts of her orbit even a moderate magnifying power makes her appear as large as our own moon. (See Fig. 5.)

Q. 10. Who was the first to discover the phases of Venus?

A. Galileo discovered the phases of Venus in 1610; this discovery furnished a strong proof for the theory of Copernicus.

Q. 11. Is Venus easily seen without instrumental aid?

A. When not too near to the sun Venus is easily seen, for this planet is by excellence the Morning and the Evening Star.

Q. 12. What are the apparent motions of the planet Venus?

A. Venus is, like Mercury, a close attendant on the sun and never departs more than 48° degrees from the Sun; when it moves east of the sun it is the beautiful Evening Star in the western sky, and when it moves west and passes the sun on its way it becomes the Morning Star.

Q. 13. What is a transit of Venus?

A. When Venus passes exactly between the earth and the sun it is then visible even without a telescope as a black spot which slowly moves across the sun's disc from east to west; this occurrence is called a transit.

Q. 14. Are transits of Venus numerous?

A. These transits occur but seldom; the last transit was December 6, 1882, and the next one will be June 8, 2004.

Q. 15. Are the transits of Venus of any importance in astronomy?

A. They were of great importance as furnishing a method of determining more closely the sun's parallax, and the distance of the earth from the sun; more exact methods have since been used to determine these important constants.

Q. 16. What made the transit-method of finding the sun's parallax less exact than was first expected?

A. The atmosphere of Venus which caused it to be surrounded by a ring of light, and a certain phenomenon of refraction which makes a sharp separation between light and darkness impossible.

Q. 17. How high is the atmosphere of Venus?

A. Astronomers judge the atmosphere of Venus to be about 55 miles high.

EXERCISE.—From a calendar determine when Venus becomes an evening star. A few months after the given date begin to look for a very bright star low down in the western horizon when the twilight begins to fade. You will notice that week after week the planet slowly increases its distance from the sun. After 220 days, counting from the time when Venus passed the sun on the eastward swing, it has attained greatest elongation, about 47°. After a moment's halt it begins to move westward and reaches the sun in about 72 days. Venus now becomes a morning star, and in 72 more days has reached its point farthest west from the sun. After 220 more days the planet is back to the position with reference to the sun and the earth from where we supposed it to start. It takes Venus, therefore, 585 days to pass through its cycle of apparent motions; this is known as the synodic period of Venus. Similarly, the synodic period of Mercury is about 116 days. Can you give the reason why the time of the westward swing is so much shorter than that of the eastward swing?

CHAPTER VII.

THE EARTH. ⊕

Q. 1. What is the earth?

A. The earth is the planet which is third in the order of distances from the sun.

Q. 2. How far is the earth away from the sun?

A. The mean distance of the earth from the sun is 92,900,000 miles; the actual distance varies about 1,500,000 miles each way from the mean distance.

Q. 3. When is the earth nearest to the sun?

A. The earth is nearest to the sun, or in perihelion, about the second of January.

Q. 4. When is it farthest away?

A. It is farthest away, or in aphelion, six months later.

Q. 5. In what time does the earth go around the sun?

A. The earth goes around the sun in $365\frac{1}{4}$ days nearly.

Q 6. Why are there leap-years?

A. To make up for the $\frac{1}{4}$ days which are dropped in ordinary years.

Q. 7. What is the plane in which the orbit of the earth lies, called?

A. It is called the ecliptic.

Q. 8. Do the orbits of the other planets also lie in the ecliptic?

A. No; none of the orbits of the other planets lie in the ecliptic, but they are all slightly inclined to it; Mercury's orbit makes the largest angle, 7°, and the orbit of Uranus the smallest angle, a little more than $\frac{3}{4}$ of a degree, with the ecliptic.

Q. 9. How fast does the earth travel through space in its orbit around the sun?

A. The earth travels with a velocity of 18.5 miles a second in its orbit; this exceeds the velocity of a cannon-ball about seventy-five times.

Q. 10. How much heat does the earth receive from the sun?

A. If the sun's heat could be distributed evenly over the earth's surface it would melt in one year a layer of ice spread over the whole earth and having a thickness of 177 feet.

Q. 11. How long does it take the sun's light and heat to reach the earth?

A. The sun's light and heat reach the earth in 8 minutes and 19 seconds.

Q. 12. What is the shape of the earth?

A. The earth is nearly a globe in shape; the other planets, their satellites and the asteroids all have this shape.

Q. 13. What causes these bodies to have the globular form?

A. These bodies are so formed according to the law of gravition.

Q. 14. What is the length of the earth's diameter?

A. The equatorial diameter of the earth is 7927 miles, and the polar diameter is 7900 miles.

Q. 15. Does this polar flattening affect the weight of bodies on the earth?

A. Yes, the polar flattening, together with the greater speed of rotation at the equator, cause bodies to weigh more (by a spring balance) when they are transferred towards the pole, although their mass remains the same.

Q. 16. How great is this difference?

A. It is one part in one hundred and ninety; a person weighing 190 pounds at the equator would weigh 191 pounds at the north pole.

Q. 17. What is the surface of the earth?

A. The earth's surface is nearly 197,000,000, square miles.

Q. 18. What is the volume of the earth?

A. The earth's volume, or solid contents, is about 260,000,000,000 cubic miles.

Q. 19. How heavy is the earth?

A. If the earth could be placed on a suitable balance it would weigh six sextillions of tons; this is about 5.5 times as much as if it were made entirely of water.

Q. 20. In what time does the earth turn on its axis?

A. It turns on its axis once in 24 sidereal hours, or in 23 hours 56 minutes 4 seconds of ordinary time.

Q. 21 What does this rotation cause?

A. This rotation causes the succession of day and night.

Q. 22. How often does the earth turn on its axis in a year of 365 days?

A. It turns 366 times on its axis. *i. e.*, any fixed star will pass the north and south line (meridian) of an observer 366 times in a year of 365 days.

Q. 23. What causes this difference of one?

A. The earth's revolution around the sun.

Q. 24. What produces the seasons?

A. The season's are due to two things, viz: the annual motion of the earth around the sun, and the

constant direction and inclination of the earth's axis of rotation to the plane of the ecliptic. (See Fig. 7)

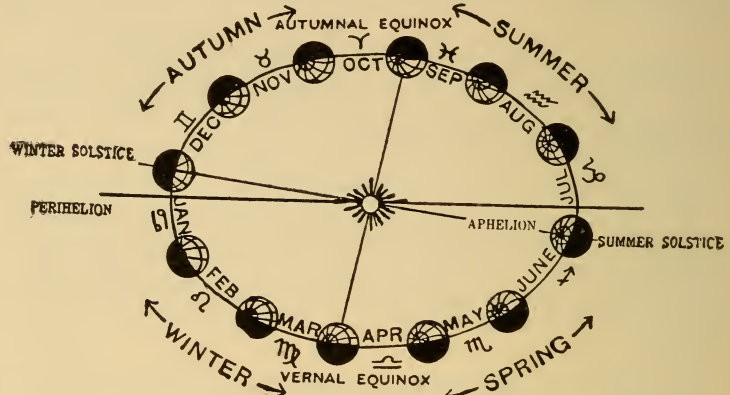

FIG. 7—THE SEASONS.

Q. 25. How great is this inclination?

A. The earth's axis is inclined to the pole of the ecliptic by an angle of a little less than $23\frac{1}{2}°$; *i. e.*, the equator makes this same angle with the ecliptic.

Q. 26. What apparent motions do the actual motions of the earth produce?

A. The daily rotation of the earth from west to east produces the apparent daily rotation of the heavenly bodies from east to west; and the annual revolution of the earth produces the apparent motion of the sun around the ecliptic, its apparent motion being always exactly opposite to the real motion of the earth.

EXERCISE. You are all, no doubt, familiar with the proofs which your geographies give for the ball-like shape of the earth. Perhaps you do not live near the big ocean or near a great lake where one can see the hulls of the ships hide behind the earth; and still you would like to see with your own eyes that the earth is

round. This is not so difficult. any lake, a mile across and even less will show it. Place a bright object (a piece of shiny tin, for instance) on one side of the lake and let it stand a few inches above the water. Then go to the other side and see how close you must bring your eye to the water in order to make the bright object disappear behind the curve of the lake's surface. The lake must, of course, be calm. In regions where the ponds are covered with ice in winter, the experiment is very easily made when the lake is smoothly frozen over. The curvature of the earth is about 8 inches to the mile. Since this curving of the surface of extended bodies of water is noticed in all regions of the earth, it follows that the earth must have a globular form.

CHAPTER VIII.

THE MOON. ☾

Q. 1. What is the moon?

A. The moon is our nearest celestial neighbor; it accompanies the earth on its journey around the sun, and it moves at the same time in an elliptical orbit around the earth.

Q. 2. How far distant is the moon from the earth?

A. The moon's mean distance from the centre of the earth is 238,800 miles; its extreme distances are 253,000 and 221,600 miles.

Q. 3. In what time does the moon complete its revolution around the earth?

A. The moon completes its revolution around the earth in 27 days, 7 hours 43 minutes; this is the average period; different revolutions may differ by several hours.

Q. 4. What is this revolution called?

A. It is called the sidereal revolution of the moon.

Q. 5. What is the synodic revolution of the moon?

A. The synodic revolution of the moon is the time from new moon to new moon again, or from full moon to full moon; its average length is 29 days, 12 hours, 44 minutes.

Q. 6. What causes this difference in time between the sidereal and the synodic revolution?

A. The change of position of the earth in her orbit.

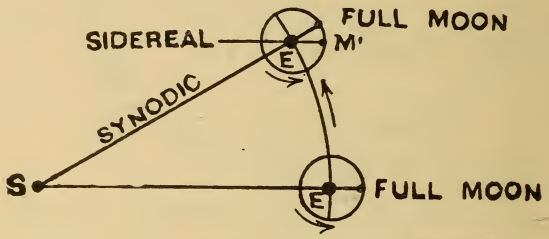

FIG. 8. SIDEREAL AND SYNODIC MONTHS.

Q. 7. At what rate does the moon travel around the earth?

A. Besides flying through space with the earth in the yearly orbit at the rate of 18.5 miles a second, the moon travels in its orbit around the earth at the rate of 2288 miles per hour.

Q. 8. What is the diameter of the moon?

A. The moon's diameter is 2160 miles. (See figure 9.)

Q. 9. How does the moon's surface and volume compare with the surface and volume of the earth?

A. The moon's surface is somewhat more than one fourteenth of the earth's surface; and its volume very nearly one forty-ninth of the earth's volume.

Q. 10. Does the moon rotate on its axis?

FIG. 9. MOON SEVEN DAYS OLD.

FIG. 10. MOON'S AGE TWENTY-ONE DAYS, FIVE HOURS.

A. Yes, the moon rotates once in a revolution, or sidereal month.

Q. 11. What does this effect?

A. It effects that the moon always presents the same side to the earth, and also that on the moon the day and the night is each roughly two weeks long.

Q. 12. Is the moon a fine object in the telescope?

A. On account of its nearness, the telescope shows comparatively smooth stretches of surface, mountain ranges, gigantic, crater-like formations and craterlets, rills, rays, etc. (See figure 10.)

Q. 13. Is there any air or water on the moon?

A. The moon has very little if any atmosphere, and no water.

Q. 14. What is meant by the moon's phases?

A. The moon's phases are the various appearances of the moon which are due to those portions of the illuminated half of the moon which are turned toward the earth.

Q. 15. How do they succeed each other?

A. At new moon, the moon stands between the sun and the earth, so that the illuminated half of the moon is entirely turned away from us; then the moon moves east of the sun in the sky and a slender cresent becomes visible of the illuminated half of the moon; the farther the moon moves away from the sun, the more becomes visible of the illuminated side, and so the crescent grows to first quarter, then to gibbous, and finally to full moon phase; at this stage the earth stands between the

moon and the sun; hereupon the moon approaches the sun again from the west and the phases become successively gibbous, last quarter, crescent, and finally, new moon phase. (See Fig. 11)

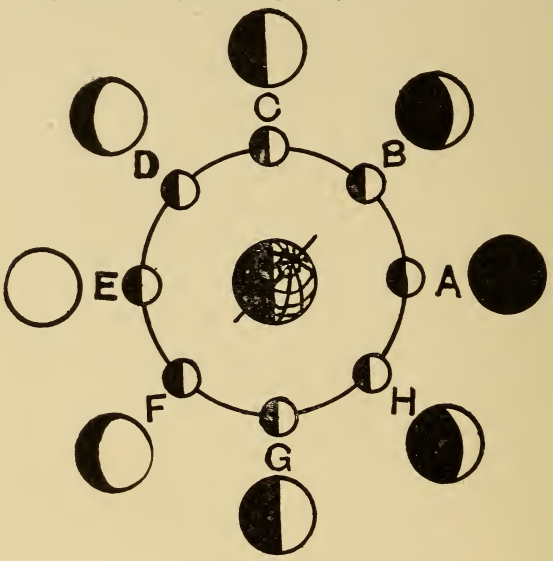

FIG. 11-PHASES OF THE MOON.

The Sun is supposed to be off to the right. A is new moon, B is the crescent visible in the evening, C is first quarter, D is the gibbons phase, E is full moon, F is the gibbons phase after full moon, G is last quarter, and H is the crescent visible in the morning sky.

Q. 16 What do the phases prove?

A. They prove that the moon is a dark body and shines by reflected light only.

Q. 17. What is the harvest moon?

A. The harvest moon is the full moon which occurs nearest to the autumnal equinox (about September 22).

Q. 18. What is remarkable about the harvest moon?

A. At the harvest moon, the moon rises for a num-

ber of evenings at nearly the same time, thus giving us a series of splendid moonlit evenings.

Q. 19. What is the cause of this?

A. The portion of the ecliptic where this full moon occurs is then least inclined to the horizon and so the moon, as it were, coasts along the horizon; since, however the moon's orbit is inclined to the ecliptic by about 5° and since the direction of this inclination continually changes, the effect is more marked in certain years than in others. The next full moon shows similar phenomena and is known as the hunter's moon.

EXERCISE. NOTE the moon's position among the stars a few days after new moon. Make a little map of the moon and the brighter stars near it. The following evening do the same and compare the two maps. The distance between the two positions will be around 13°. At that rate, how many days would it require to make the whole circle of 360°? Examine if there are any bright stars in the moon's path to the east of the moon. If there is one quite close to the moon, observe how the moon passes in front of the star and hides it from our view. This phenomenon is called an occultation. The disappearance is instantaneous, and affords one of the best proofs that the moon has no atmosphere, or, at most, an extremely rare one. An opera glass will be of great help in observing this very striking and interesting phenomenon.

CHAPTER IX.

ECLIPSES.

Q. 1. What is an eclipse of the sun?

A. An eclipse of the sun is the partial or total hiding of the sun's disc by the moon.

Q. 2. What is a total eclipse?

A. An eclipse of the sun is total when the sun is entirely hidden by the moon. (See Fig. 12)

Q. 3. How long may a total eclipse last?

A. From first to last contact may take a little

more than four hours; the time of total obscuration can never exceed 7 minutes 58 seconds, and is usually much less.

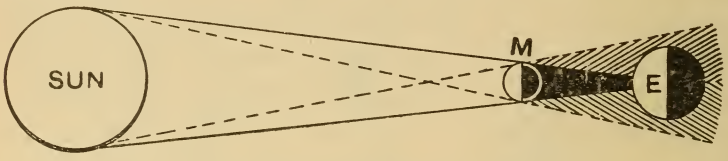

FIG. 12—TOTAL ECLIPSE OF THE SUN.

Q. 4. Is a total eclipse of the sun visible in widely distant places?

A. A total eclipse is visible only within a very long but narrow strip of the earth's surface; the eclipse is however visible as a partial one to big distances on either side of the path of totality.

Q. 5. What is a partial eclipse of the sun?

A. At a partial eclipse, the sun, moon, and earth do not get quite in line and the moon covers up the sun only partly.

Q. 6. What is an annular eclipse?

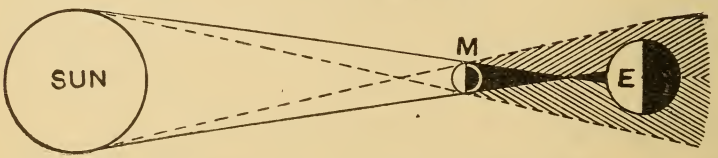

FIG. 13. ANNULAR ECLIPSE OF THE SUN.

A. At an annular eclipse the moon is too far away from the earth so that its shadow cannot reach the earth; the moon appears therefore smaller than the sun and in passing in front of the sun will leave a ringlike portion of the sun unobscured.

Q. 7. When does an eclipse of the moon occur?

A. An eclipse of the moon takes place when the moon passes through the earth's shadow; in other words, when the earth stands between the sun and the moon. (See Fig. 14.)

Q. 8. When is a lunar eclipse total, and when partial?

A. It is total when the moon passes entirely into the earth's shadow, and partial, when the moon gets only partly within this shadow.

Q. 9. How long can an eclipse of the moon last?

A. A total eclipse of the moon may last under best conditions about four hours from first to last contact; the time of total obscuration is about two hours.

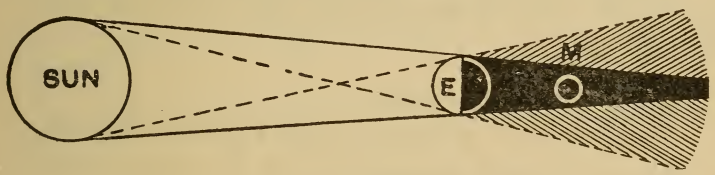

FIG. 14. TOTAL ECLIPSE OF THE MOON.

Q. 10. Is an eclipse of the moon widely visible?

A. Yes, an eclipse of the moon is visible from the half of the earth's surface which is turned toward the moon.

Q. 11. At what time only, can eclipses occur?

A. Eclipses of the sun can occur at new moon only, and eclipses of the moon occur only at full moon.

Q. 12. Why are there not eclipses at every new moon and every full moon?

A. Because the moon's orbit is inclined to the ecliptic where the eclipses occur by an angle of over

5°, hence the moon is but twice a month in the ecliptic, when it crosses it from above and from below; only when these points of crossing, called the nodes, lie in line with the sun and the earth do eclipses take place.

Q. 13 Are eclipses of frequent occurrence?

A. Two eclipses, at least, must occur each year, and these would be eclipses of the sun; the greatest number that can take place in a year is seven, and of these five would be of the sun and two of the moon.

Q. 14. Are eclipses of the sun more frequent than eclipses of the moon?

A. Yes, there are about four solar eclipses to three lunar eclipses; the lunar eclipses are however more widely visible.

Q. 15. What is the Saros?

A. The Saros is a period of time equal to eighteen years and eleven and one-third days; if there should however be five leap years in this interval, then instead of eleven and one third, ten and one-third days are taken.

Q. 16. What purpose does the Saros serve?

A. The Saros has been used from remote antiquity on in foretelling eclipses.

Q. 17. How is it applied?

A. If there was an eclipse of the sun or of the moon on a certain date, then eighteen years eleven and one-third days later a like eclipse will happen; in this manner an eclipse of the moon will be repeated nearly

fifty times, and an eclipse of the sun will be repeated around seventy times.

Q. 18. What is the cause of this recurrence?

A. In the interval of a Saros the moon gets very nearly back to the position it occupied with reference to the sun and the nodes.

Q. 19. When was the last total eclipse of the sun which was visible in the United States?

A. The last total solar eclipse visible in the United States was on May 28th, 1900.

Q. 20. When will the next eclipses of the sun occur, which are total eclipses somewhere in the United States?

A. They will occur in 1918, 1923 and 1925.

Exercises.

From a calendar find out if any of the eclipses which occur during the year are visible in the region where you live. If they be eclipses of the moon, no special preparations are necessary. Note at what side the shadow cast by the earth begins to encroach upon the lunar landscape. If it be a total eclipse, the moon will most probably remain visible even at greatest totality; but it will shine with a dull copper-colored light; this is light which is bent into the shadow by the earth's atmosphere. If they be eclipses (partial) of the sun, some sort of shade to reduce the brilliancy of the sun will be necessary. Light a small piece of camphor and hold a piece of an ordinary window-pane over the flame. The glass will soon be covered with a layer of soot through which one can easily view the sun. Note from what direction the moon encroaches upon the sun's disc. Can you explain from a knowlege of the moon's motion among the stars why it should be in that direction? If it be your good fortune to get within the path of totality of a total solar eclipse, you should make beforehand a study of the phenomena attending a solar eclipse in order to view properly what is one of the grandest of natural events.

CHAPTER X.

The Tides.

Q. 1. What are the tides?

A. The tides are the periodical rising and falling of the water of the ocean.

Q. 2. How often does the water of the ocean rise and fall?

A. The water rises and falls twice in the interval of a little more than a day; the average interval being 24 hours 51 minutes.

Q. 3. When is it flood tide?

A. It is flood tide when the water is rising.

Q. 4. When is it ebb tide?

A. It is ebb tide when the water is falling.

Q. 5. What are spring tides?

A. Spring tides are the highest tides of the month.

Q. 6. When do they occur?

A. They occur at the time of new moon and full moon.

Q. 7. What are neap tides.

A. Neap tides are the smallest tides of the month.

Q. 8. When do they occur?

A. They occur at the time of first quarter and last quarter of the moon.

Q. 9. How much higher, about, are the spring tides than the neap tides?

A. The spring tides are about $1\frac{3}{4}$ times as high as the neap tides.

Q. 10. Are tides of any use?

A. Yes, at time of flood tide large ships can ascend shallow harbers that would otherwise be inaccessible to them.

Q. 11. What causes the tides?

A. The attraction of the moon and the sun causes the tides; but more especially the attraction of the former.

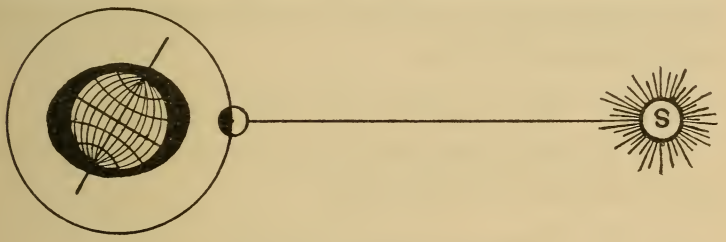

FIG. 15.—SPRING TIDE.

Q. 12. Why is the tide-raising force of the moon greater than that of the sun?

A. Because the moon is so much nearer to the earth.

Q. 13. What fraction of the moon's tide-raising force is the sun's tide-raising force?

A. It is about $\frac{2}{5}$ of the moon's tide-raising force.

Q. 14. How many flood tides are produced by the moon or by the sun at any one time?

A. There are always two tides produced by these bodies; one is, in general, turned towards them, and the other is on the other side of the earth turned away from them.

Q. 15. How are these double tides to be explained?

A. Since the tides are a consequence of the attraction of these bodies, and since the attraction varies inversely as the square of the distance, it follows, that the part of the earth's surface turned toward the moon, for instance, is drawn more than the earth's centre, and that the earth's centre is drawn more than the surface turned farthest away; hence the waters of the ocean will bulge out in these directions as much as their elasticity, weight and inertia will allow.

Q. 16. Where are the ebb tides situated?

A. The ebb tides are situated half-away on either side between the flood tides.

Q. 17. When are the tides highest?

A. The tides are highest when the moon and the sun are nearest to the earth.

Q. 18. What causes the spring tides?

A. At new moon or full moon, the sun and the moon are in line with the earth, hence their tide-raising forces are combined.

Q. 19. What causes the neap tide.

A. At first quarter and last quarter of the moon, the sun and moon are at right angles with the earth, hence the sun's flood tide coincides with the moon's ebb tide so that the solar flood tide partly fills out the drepression of the lunar ebb tide; likewise, the sun's ebb tide and the moon's flood tide then occupy the same position, in consequence of which, the lunar flood tide will be lowered by a corresponding amount.

Q. 20. In what direction do the tides travel?

A. Since the apparent daily motion of the sun and moon is from east to west, the general direction of travel of the tidal wave is from east to west also.

Q. 21. Are the tides much modified in their onward motion?

A. Yes, the tides are very much modified by the varying depth of the oceans and by the continents that stretch like gigantic barriers across the path of the tidal wave.

CHAPTER XI.

MARS. ♂ THE SATELLITES OF MARS.

Q 1. Where is Mars situated?

A. The orbit of Mars is next outside of the orbit of the earth.

Q 2. How far is Mars from the sun?

A. The mean distance of Mars from the sun is 141,500,000 miles; but it varies about 13,000,000 miles each way from the mean.

Q. 3. In what time does Mars complete a revolution around the sun?

A. Mars completes its revolution around the sun in 687 days.

Q. 4. How fast does Mars move along in its orbit?

A. Mars has an orbital velocity of 15 miles per second.

Q. 5. How strong is the sun's light and heat at the distance of Mars?

A. At the distance of Mars the sun's light and heat is only about 43 per cent. as intense as it is at the distance of the earth.

Q. 6. How many miles is Mars in diameter?

A. The diameter of Mars is 4,200 miles.

Q. 7. What is this planet's surface and volume?

A. Its surface is 28 per cent. of the earth's surface and its volume is $\frac{1}{7}$ of the earth's volume.

Q. 8. How does the surface gravity on this planet compare with that of the earth?

A. Since Mars is less dense than the earth (0.73), its surface gravity comes out 0.38 of the earth's surface gravity; in other words, a body which weighs one hundred pounds on earth would weigh thirty-eight pounds on Mars.

Q. 9. In what time does Mars turn on its axis?

Mars turns on its axis once in 24 hours 37 minutes 22.67 seconds; its day is therefore a little longer than a day on earth.

Q. 10. Is the equator of Mars inclined to the plane of its orbit?

A. Its equator is inclined to the plane of its orbit by an angle of 24° 50′; the seasons, therefore, in as far as being dependent on the inclination of the equator, must resemble the seasons here on earth.

Q. 11. How does Mars appear when viewed with a telescope?

A. Considerable detail of this planet's features has been observed with large telescopes.

Q. 12. Which are some of the objects viewed?

A. The white polar caps, patches of bluish or greenish shade forming about three-eighths of the planet's surface, large areas of orange shade, the so-called canals, and the oases are the principal features observable on Mars.

FIG. 16. TELESCOPIC VIEWS OF MARS.

Q. 13. What interesting change is noticed in the polar caps?

A. The polar caps grow large when the respective pole is turned away from the sun, and grow small or even disappear altogether when, half a Martian year later, they are turned to the sun; in this manner they strongly suggest the advance and retreat of snow and ice during the seasons here on earth.

Q. 14. What are the bluish or greenish patches?

A. It has been thought that they are bodies of water.

Q. 15. What are the orange portions?

A. It seems quite probable that the orange portions are dry land.

Q. 16. What are the canals?

A. These were first discovered by Schiaparelli in 1877; Lowell and others think that they are water courses together with the vegetation which, they suppose, grows on either side of the canals.

Q. 17. What are the oases?

A. The oases are small round patches which are situated at the intersections of two or more canals; they are also supposed to be principally due to vegetation.

Q. 18. Is Mars inhabited?

A. Though Mars receives so very much less light and heat from the sun than the earth, still no other planet approaches terrestrial conditions as nearly as Mars does; it has been argued that the straightness of the canals and their converging to certain points is an indication of their having been constructed under intelligent direction, and that for this reason, rational beings must live on Mars; the argument is, however, not conclusive and the Martians meanwhile remain hypothetical beings for the inhabitants of the earth.

Q. 19. How does Mars appear to the naked eye?

A. In the sky Mars appears as a dusky red star, at times it outrivals Jupiter in brightness.

Q. 20. What causes this difference in brightness?

A. The planet is brightest when it is nearest to us or in opposition; its average distance is then 48,600,000 miles; it is faintest when it is farthest

away from the earth or in superior conjunction, its average distance is then 234,400,000 miles.

Q. 21. Has Mars any Moons?

A. In 1877 Professor Hall at Washington discovered two little satellites, or moons of Mars.

Q. 22. What did he call them?

A. He named them Deimos and Phobos, which means "Dread" and "Terror".

Q. 23. How far are they from Mars?

A. Deimos is 14,000 miles from the center of Mars and goes around it in 30 hours 18 minutes; Phobos is only 5,800 miles away and goes around Mars in 7 hours and 39 minutes.

Q. 24. What peculiarity does this short month of Phobos produce?

A. It effects that Phobos rises in the west and sets in the east.

Q. 25 How large are these moons?

A. Deimos, the smaller one, has been estimated to be from 5 to 10 miles in diameter, and Phobos from 7 to 25 miles.

EXERCISE. From a calendar find out if Mars comes to opposition during the year. This occurs at intervals of 780 days (2 yrs. $1\frac{2}{3}$ mos.). The planet's ruddy color will help you to identify it. Since there are a number of fixed stars that resemble it, when merely viewed with the eye, one must make sure that it is the planet If the suspected planet changes its position relative to the other star in the course of a few weeks, it is Mars; if not, it is a fixed star, and the star-maps will tell you what star it is, and to what constellation it belongs.

CHAPTER XII.

THE ASTEROIDS.

Q. 1. What are the asteroids?

A. The asteroids, or planetoids, are small, planet-like bodies which circle around the sun in orbits of their own and which are situated between the orbits of Mars and Jupiter.

Q. 2. When was the first asteroid discovered?

A. Piazzi, an astronomer of Sicily, discovered the first asteroid on Jan. 1, 1801, and named it Ceres.

Q. 3. What asteroids were discovered next?

A. In 1802, Dr. Olbers discovered Pallas; in 1804, Harding discovered Juno; and in 1807, Dr. Olbers discovered Vesta, which is the brightest of the asteroids and sometimes becomes visible to the naked eye.

Q. 4. When were some more asteroids discovered?

A. The fifth asteroid, Astraea, was discovered in 1845 by Henke, in 1846 none were found, in 1847 three were discovered, and since that time every year has added one or more to their number.

Q. 5. How many asteroids have been found?

A. Over five hundred have been found already, but the great majority is very small, many are probably not more than 10 miles in diameter.

Q. 6. What is the total number of asteroids?

A. For various reasons, astronomers think that the total number is very large—many thousands, if not millions.

Q. 7. How large are the diameters of the four brightest asteroids?

A. According to Barnard's measurements, which are however affected by a large probable error, the diameter of Ceres is 485, of Pallas 304, of Juno 118, and of Vesta 243 miles.

Q. 8. Which asteroid is nearest to the sun?

A. Eros, (433), the asteroid which was discovered by Witt in 1898, is nearest to the sun; its mean disance is not quite 135,480,000 miles; this is less than the mean distance of Mars from the sun, but, on account of the comparatively large eccentricity of its orbit. it recedes at Aphelion more than 11,000,000 miles further from the sun than Mars does.

Q. 9. How near can Eros approach the earth?

A. It comes at times within a distance of $13\frac{1}{2}$ million miles from the earth; this is a little more than half the least distance within which Venus can approach the earth.

Q. 10. Is Eros of any use to astronomers?

A. Yes, the close approaches of Eros furnish the most exact means known to obtain that astronomical quantity, called the solar parallax, upon which all astronomical distances depend.

Q. 11. What is the period of Eros?

A. Eros completes its revolution around the sun in 643 days.

Q. 12. Which asteriod is farthest from the sun?

A. Thule, (279), is the remotest of the asteroids;

its mean distance is 400,000,000 miles and its period is 8 years 313 days.

Q. 13. Do the orbits of the asteroids all lie in the same plane?

A. No, some orbits are greatly inclined to the ecliptic and their eccentricities are so various, that if the orbits were represented by rigid hoops, one would lift them all by trying to lift any one of them, so much are they tangled.

Q. 14. By what method are asteroids discovered nowadays?

A. Nowadays, the photographic method is employed in discovering asteroids; *i. e.*, a portion of the sky is photographed with a specially made and mounted stellar camera; the stars will appear like dots on the plate, but any asteroids, having a proper motion of their own among the stars, will show this motion by a small trail on the plates.

Q. 15. What is the origin of the asteroids?

A. The origin of the asteroids is as yet a matter of speculation; one view holds, that they are the result of a series of explosions which took place, from some unknown cause, in a planet which moved between Mars and Jupiter; the other view, which seems more probable, holds, that for some reason, the nebulous matter of which the planets are made, failed to be gathered in one large planet, but instead, was distributed to form this swarm of miniature earths.

CHAPTER XIII.

JUPITER. ♃

Q. 1. At what distance does Jupiter revolve around the sun?

A. Jupiter revolves at a mean distance of 483,000,000 miles around the sun.

Q. 2. In what time does this planet complete a revolution around the sun?

A. It completes a revolution in 11.86 years.

Q. 3. With that velocity does it travel in its orbit?

A. Jupiter's orbital velocity is a little over 8 miles a second.

Q. 4. What is the intensity of the sun's light and heat at the distance of Jupiter?

A. The sun's light and heat on Jupiter is only one twenty-seventh as intense as it is on the earth.

Q. 5. What is the diameter of Jupiter?

A. The mean diameter of Jupiter is 86,500 miles; its equatorial diameter is 88,200, and its polar diameter is 83,000 miles*.

Q. 6. How much greater is its surface and volume than the surface and volume of the earth?

A. Its surface is 119 times, and its volume 1,300 times as large as that of the earth?

*NOTE.—The mean diameter of a planet is found by adding the polar diameter to twice the equatorial diameter and dividing this sum by three. Evidently of the three axes of symmetry, one is the polar diameter and the other two lie at right angles in the equator.

Q. 7. Is Jupiter the largest of the planets?

A. Yes, Jupiter is the giant among the planets; its volume as well as its mass is larger than that of all the other planets combined.

Q. 8. How heavy would a body which weighs a 100 pounds on earth be on Jupiter?

A. It would weigh 264 pounds.

Q. 9. Does Jupiter rotate on its axis?

A. Yes, this giant planet turns once on its axis in about 9 hours, 55 minutes.

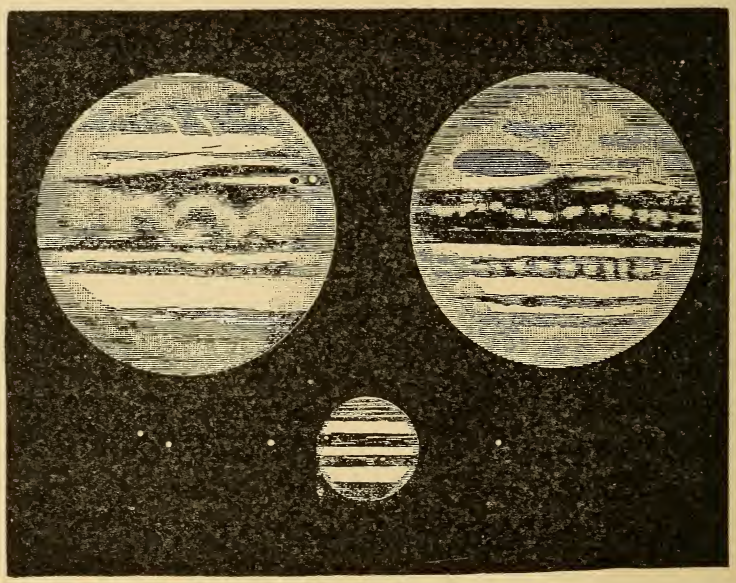

FIG. 17.—TELESCOPIC VIEWS OF JUPITER.

Q. 10. What is peculiar about its rotation?

A. As upon the sun, regions near the equator rotate

more rapidly than portions towards the polls; this would indicate that Jupiter has as yet no solid surface, or that all the spots and markings are simply features of its atmosphere.

Q. 11. How fast do the equatorial regions move on account of the planet's rotation?

A. They move with a velocity of over 26,000 miles an hour.

Q. 12. Is the plane of the equator inclined to that of the orbit?

A. There is an angle of only 3° between these planes; hence, there are no seasons on Jupiter due to the sun.

Q. 13. How does Jupiter appear in a telescope?

A. Jupiter is a beautiful object for the telescope; even a small one reveals a great amount of detail.

Q. 14. Which are the most conspicuous features?

A. The most conspicuous features are the belts, which have a dark color.

Q. 15. How are they situated?

A. They are arranged parallel to the equator; generally there is a broad belt on each side of the equator and several narrow ones alongside of these; the number and shape of the belts varies considerably.

Q. 16. What are these belts supposed to be?

A. They are thought to be cloud-forms which are arranged in belt-like layers on account of the rapid rotation of the planet.

Q. 17. What other features are observed?

A. A great number of temporary black and white spots have been observed; in 1878 a large spot of reddish hue appeared; it was 30,000 miles long and 7,000 wide, and was situated on the south side of the south-equatorial belt; it was a conspicuous object for years, but has since become very faint.

Q. 18. Did this spot have the same period of rotation as its surroundings?

A. No, its rotation period was about 22 seconds longer than its surroundings; in consequence of this, the spot was like an island in a river, past which the current drifts at a rate of 12 to 15 miles an hour.

Q. 19. Is Jupiter self-luminous?

A. Since the moons of Jupiter suffer total eclipse when they come into its shadow, it becomes certain that Jupiter is not self-luminous or at least but very faintly so, but it is universally held that the planet must still be very hot.

Q. 20. How does Jupiter appear to the naked eye?

A. Jupiter, the second brightest of the planets, appears nearly white in color; on the average it is five times brighter than Sirius, which is the brightest fixed star; and it is each year for several months one of the chief ornaments of the evening sky.

Q. 21. How does this planet move among the stars?

A. It slowly moves eastward among the stars for a little over 8 months, then comes to a halt, moves

westward with reference to the stars for nearly 4 months and then resumes its eastward journey.

Q. 22. Do these forward and backward motions lie along a line?

A. No, when the motions of the planets are plotted on a map they have the appearance of curious loops and kinks.

EXERCISE.—When a planet is in opposition it is on the meridian (the north and south line) at midnight. It will, therefore, be east of the meridian during the evening hours. Look up in a calendar during what month of the year Jupiter comes to opposition. With this knowledge it will be an easy matter to find the planet, which, when once recognized, will always be known again. It will return to the same relative position with regard to the sun and the earth in 399 days, a little more than a year and a month.

CHAPTER XIV.

JUPITER'S SATELLITES.

Q. 1. How many satellites has Jupiter? *

A. Jupiter has five satellites which move around it from west to east at different distances and with different periods.

*On January 4, 1905, Perrine, of Lick Observatory, announced the discovery of a sixth satellite of Jupiter, and on January 6, he discovered a seventh satellite. Both satellites are quite faint. Their direction of motion is not yet definitely known. The sixth satellite is about 7,000,000 miles from Jupiter. Its orbit of revolution is considerably inclined to that of Jupiter. This satellite's period of revolution is about 250 days. It is estimated to be of the fourteenth magnitude, and Perrine thinks its diameter is 100 miles or less. The seventh satellite is about 6,000,000 miles from Jupiter. Its orbit of revolution is quite eccentric and is inclined to that of Jupiter. It completes a revolution in about 200 days. This satellite is estimated to be of the sixteenth magnitude, and to have a diameter of about 35 miles.

Q. 2. When and by whom were the four outer and larger ones discovered?

A. In 1610 the four outer satellites were dis covered by Galileo; they were the first heavenly bodies ever discovered.

Q. 3. How are these satellites distinguished?

A. The nearest of the four is designated by the Roman numeral I., the second by II., the third by III., and the fourth by IV.; they are also known by the names: Io, Europa, Ganymede, and Callisto.

Q. 4. At what distance is I. from Jupiter?

A. The distance of I. from Jupiter is 261,000 miles.

Q. 5. What time does it require to move around its primary?

A. It completes its revolution around Jupiter in 1 day 18 hours 27 minutes 33.5 seconds.

Q. 6. What is the distance of II.?

A. The distance of II. from Jupiter is 415,000 miles.

Q. 7. What is its period?

A. The period of II. is 3 days 13 hours 13 minutes 42 seconds.

Q. 8. What is the distance of III.?

A. The distance of III. is 664,000 miles.

Q. 9. What is its period?

A. The period of III. is 7 days 3 hours 42 minutes 33 seconds.

Q. 10. At what distance does IV. move around Jupiter?

A. The distance of IV. from its primary is 1,167,000 miles.

Q. 11. In what time does it complete a revolution?

A. It completes a revolution in 16 days 16 hours 32 minutes 11 seconds.

Q. 12. Who discovered the fifth and innermost of Jupiter's satellites?

A. Barnard discovered the fifth satellite of Jupiter in 1892 with the big Lick telescope; it is, perhaps, not 100 miles in diameter and only the large telescopes will show it.

Q. 13. What is the fifth satellite's distance from Jupiter?

A. The distance of the fifth satellite is 112,500 miles.

Q. 14. What is its period?

A. Its period is 11 hours 57 minutes 22.6 seconds.

Q. 15. What are the diameters of Jupiter's moons?

A. The diameter of I is 2,500 miles, of II 2,100, of III 3,550; and of IV 2,960.

Q. 16. Do the moons of Jupiter also rotate?

A. From observations of certain markings on their discs it is probable that the third and fourth satellites rotate once during the time that they revolve around Jupiter; in other words, their period of rotation is equal to their period of revolution.

Q. 17. In what plane do the satellites revolve?

A. They all revolve in planes which very nearly coincide with the primary's equator.

Q. 18. What is the consequence of this?

A. The moons are eclipsed at each revolution, and likewise transit across the planet's disc; the fourth moon alone at times escapes eclipse.

Q 19. What use has been made of these eclipses?

A. In 1675, Roemer noticed that the eclipses occurred successively later than predicted by the tables, when the distance between Jupiter and the earth was increasing, and, vice versa, the phenomena occurred successively earlier, when the earth and Jupiter were approaching each other; this is explained as due to the time it takes light to travel through space.

EXERCISE. If you have a good opera glass at your disposal direct it to Jupiter. You will most likely see one or the other of Jupiter's moons as a tiny star near it. Observations for several evenings in succession will show that these tiny stars accompany Jupiter in its motion among the stars and that they themselves seem to move in a nearly straight line, now to the east and then to the west of their primary, each one having a fixed distance beyond which it cannot go.

CHAPTER XV.

SATURN. ♄

Q. 1. What planet comes next after Jupiter?

A. It is the planet Saturn.

Q. 2. How far is it away from the sun?

A. Its mean distance is 886,000,000 miles.

Q. 3. In how many years does it move once around the sun?

A. This planet moves around the sun once in $29\frac{1}{2}$ years.

Q. 4. At what rate does it travel in its orbit?

A. It travels at the rate of six miles per second around the sun.

Q. 5. What is the intensity of the sun's light and heat at Saturn's distance?

A. At this distance the sun's light and heat are only $\frac{1}{91}$ as intense as at the earth's distance.

Q. 6. What is the diameter of Saturn?

A. The mean diameter is 73,000 miles; the equatorial diameter is 75,000, and the polar is 68,000 miles.

Q. 7. What is its surface and volume?

A. Saturn's surface is about 82 times, and its volume 760 times that of the earth.

Q. 8. Does Saturn rotate?

A. Yes, it rotates upon its axis in about 10 hours and 14 minutes.

Q. 9. Is this planet's equatorial plane inclined to the plane of its orbit?

A. It is inclined by an angle of about 27°.

Q. 10. How does Saturn appear in a telescope?

A. Saturn is a unique and splendid object in the

telescope, and the first view generally draws forth an exclamation of wonder and delight.

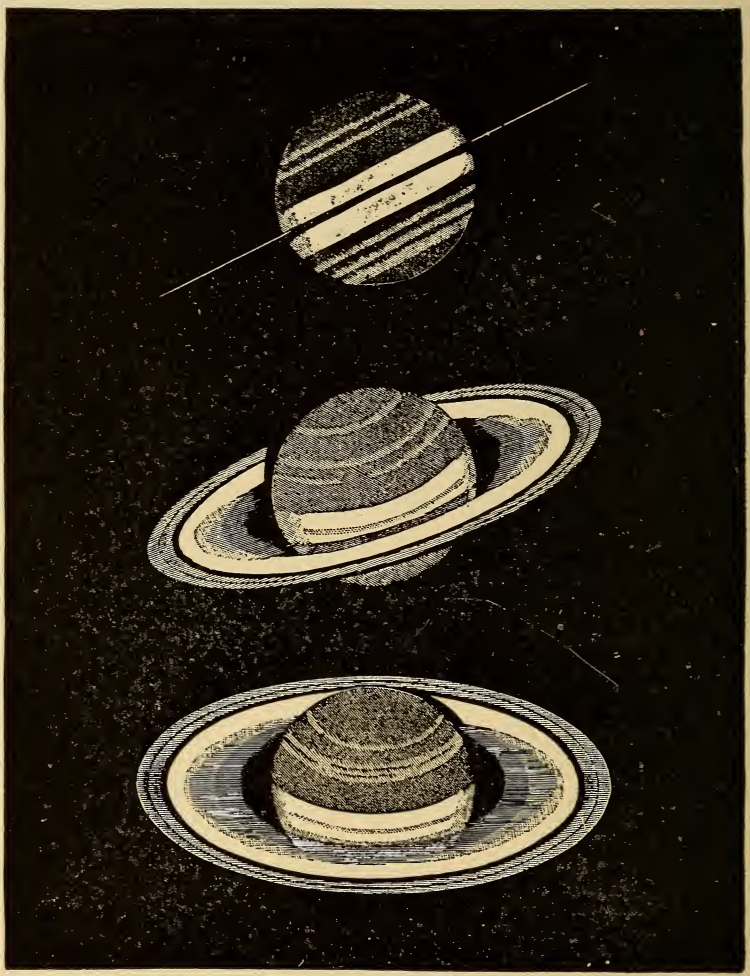

FIG. 18—SATURN AND ITS RINGS.

Q. 11. What is most striking in its appearance?

A. Its belts, which are however not as conspicuous and changeable as those of Jupiter; and above all, its magnificent ring-system. (See Fig. 18)

Q. 12. How many rings are there?

A. There are three concentric rings; the two outer ones are bright, but the one nearest to the planet is dusky, and is therefore sometimes called the gauze or "crape" ring.

Q. 13. Where are the rings situated?

A. They are situated in the planet's equator.

Q. 14. What are the dimensions of the rings?

A. The outer ring has an exterior diameter of 168,060 miles and it is a little more than 10,000 miles wide; between it and the middle ring is a clear space about 1,600 miles in width; the middle ring is about 16,500 miles wide; immediately joining the middle ring is the dusky ring, which is about as wide as the outer ring; hence there is left a clear space between the inner edge of this ring and the planet's surface, which has a width of about 9,000 or 10,000 miles.

Q. 15. How thick are the rings?

A. As compared with their other dimensions, the rings are very thin; the thickness does probably not exceed 100 miles.

Q. 16. Of what are the rings composed?

A. They are composed of a swarm of separate particles, the outer particles revolving more slowly than the inner ones.

Q. 17. Do the rings contain much matter?

A. Since the rings produce no appreciable pertubations in the motion of the satellites, their mass must be quite small.

Q. 18. Do the rings ever become invisible?

A. Since the plane of the rings always remains parallel to itself as Saturn journeys around the sun, it follows that the edge of the rings is turned towards the earth twice at every revolution; when the rings are turned edgewise towards the earth they become invisible for a few days, even in the largest telescopes; some time before and after, they appear like a thin needle of light, the planet then resembles a bright ball which is pierced by a luminous knitting-needle.

Q. 19. At what intervals do the rings become invisible?

A. They become invisible about once every 15 years.

Q. 20. When will they disappear next?

A. They will disappear again in 1907.

Q. 21. How does Saturn appear among the stars?

A. Saturn generally appears like a star of the first magnitude, and has a decided yellowish tint.

Q. 22. How does Saturn move among the stars?

A. It moves eastward for about $7\frac{1}{2}$ months and westward for about $4\frac{1}{2}$.

Q. 23. Does this planet depart far from the ecliptic?

A. No, Saturn never departs more than about $2\frac{1}{2}°$ from the annual path which the sun traverses in the sky.

EXERCISE—Determine by a calendar in what constellation Saturn is at the time. An aid for identification is the absence of the twinkling (unless the planet is too near the horizon) which is characteristic of the fixed stars. All the planets shine with a steady light. Mark down Saturn's position with reference to the brighter stars of the constellation. A year later you will find Saturn a little east of where you located it in your drawing, and probably it is still in the same constellation, as it takes Saturn about $2\frac{1}{2}$ years to move through one of them. Saturn is the remotest planet which was known to the ancients.

CHAPTER XVI.

THE SATELLITES OF SATURN.

Q. 1. How many satellites has Saturn?*

A. Saturn has nine satellites.

Q. 2. What are their names in the order of distances from Saturn?

A. Their names are: Mimas, Enceladus, Tethys, Dione, Rhea, Titan, Hyperion, Japetus, and Phoebe.

Q. 3. What is the distance from Saturn and the period of revolution around Saturn of Mimas?

A. The distance of Mimas is 117,000 miles; its period of revolution is 22 hours 37 minutes.

*A tenth satellite of Saturn was discovered by Prof. W. C. Pickering. It has an estimated diameter of 200 miles, and is beyond telescopic vision. Its period of revolution is 21 days, which is a little less than that of Hyperion, and the motion is direct. The plane of its orbit is considerably inclined to the plane of the rings.

Q. 4. What is the distance and period of Enceladus?

A. The distance of Enceladus is 157,000 miles; its period is 1 day 8 hours 53 minutes.

Q. 5. Who discovered these moons?

A. Sir William Herschell discovered these two in 1789.

Q. 6. What is the distance and period of Tethys?

A. The distance of Tethys is 186,000 miles; its period is 1 day 21 hours 18 minutes.

Q. 7. What is the distance and period of Dione?

A. The distance of Dione is 238,000 miles; its period is 2 days 17 hours 4 minutes.

Q. 8. When were Tethys and Dione discovered?

A. They were discovered in 1684 by J. D. Cassini.

Q. 9. What is the distance and period of Rhea?

A. The distance of Rhea is 332,000 miles; its period is 4 days 12 hours 25 minutes.

Q. 10. Who is the discoverer of Rhea?

A. Cassini discovered the satellite Rhea in 1672.

Q. 11 What is the distance and period of Titan?

A. The distance of Titan is 771,000 miles; its period is 15 days 22 hours 41 minutes.

Q. 12. When was Titan discovered?

A. Titan was discovered in 1655 by Huyghens.

Q. 13. What is the distance and period of Hyperion?

A. The mean distance of Hyperion is 934,000 miles; its period is 21 days 6 hours 39 minutes.

Q. 14. Who discovered Hyperion?

A. G. P. Bond of Cambridge, Mass., discovered Hyperion in 1848; two days later, it was discovered independently by Lassell of Liverpool.

Q. 15. What is the distance and period of Japetus?

A. The distance of Japetus is 2,225,000 miles; its period is 79 days 7 hours 54 minutes.

Q. 16. Who discovered Japetus?

A. In 1671, Japetus was discovered by Cassini.

Q. 17. In what direction do these moons revolve around Saturn?

A. Their motion is direct; *i. e.*, they move around Saturn from west to east, just as the primary planets move around the sun.

Q. 18. What is the distance and period of Phoebe?*

A. The mean distance of Phoebe is 7,996,000 miles; its period is 546.5 days, which is just one day short of a year and a half.

Q. 19. By whom was Phoebe discovered?

A. Phoebe was discovered by W. Pickering, at Arequipa, by means of photographs, which were taken for the purpose of discovering just some such satellite like Phoebe, if there were any; this was in 1898.

* The data regarding Phoebe are taken from Vol. LIII, No. 3, of the Annals of Harvard College Observatory. The data are not final and will probably be somewhat changed by further observations.

Q. 20. Is Phoebe a faint object?

A. Phoebe is an extremely faint object; its brightness is estimated at two magnitudes fainter than that of Hyperion, which is assumed to be of the 14.0 magnitude; according to Young, the Yerkes telescope, which has an aperture of forty inches and which is the largest refractor in existence, "will barely show stars of the seventeenth magnitude;" Phoebe is therefore just about on the limit of visibility even for the largest telescopes.

Q. 21. What is the diameter of Phoebe?

A. "From photometric considerations its diameter is thought to be about 200 miles."

Q. 22. What is peculiar about Phoebe's orbit?

A. Its orbit is very eccentric, the eccentricity being 0.22; hence the distance of this satellite from Saturn varies over 1,700,000 miles each way from the mean distance.

Q. 23. What is peculiar about its motion?

A. Its motion is retrograde or opposite to the motion of the other satellites of Saturn.

Q. 24. How bright would Phoebe appear from Saturn?

A. It would shine like a star of magnitude 5.2 to 6.2, depending on its distance from that body; in other words, it would appear like the faint stars that we can just see with the naked eye.

CHAPTER XVII.

URANUS. ♅ THE SATELLITES OF URANUS.

Q. 1. Where is the orbit of Uranus?

A. The orbit of Uranus is situated between the orbits of Saturn and Neptune.

Q. 2. When and by whom was Uranus discovered?

A. Uranus was discovered by William Herschel in 1781.

Q. 3. Had Uranus been seen before 1781?

A. Yes, Uranus had been observed and its position recorded by Flamsteed, Bradley, Mayer and Lemonnier, in all not less than 19 times before 1781; but these astronomers failed to recognize it as a planet.

Q. 4. What is the distance of Uranus from the sun?

A. The mean distance of Uranus is very nearly 1,800,000,000 miles.

Q. 5. In what time does Uranus complete a revolution around the sun?

A. It completes a revolution in 84 years 6.5 days.

Q. 6. How fast does Uranus travel in its orbit?

A. The orbital velocity of Uranus is 4.2 miles per second.

Q. 7. How much light and heat does this planet receive from the sun?

A. The sun's light and heat at Uranus is only $\frac{1}{368}$ as intense as it is at the earth.

Q. 8. What is the diameter of Uranus?

A. The diameter is about 32,000 miles, but this number is still uncertain by several thousand miles.

Q. 9. What is the surface and volume of this planet?

A. Assuming the above number for its diameter, the surface is about 16 times, and the volume about 66 times greater than that of the earth.

Q. 10. Is the period of rotation of Uranus known?

A. Until now, it has not been possible, on account of the absence of distinct markings on the surface, to determine in what time Uranus turns on its axis.

Q. 11. How does Uranus appear in the telescope?

A. It has the appearance of a small disc of sea-green color; at times also very faint belts are visible.

Q. 12. Can Uranus be seen without telescopic aid?

A. Yes, Uranus shines like a star of the sixth magnitude; sixth magnitude stars are the faintest stars that are visible to the naked eye.

Q. 13. What is the apparent motion of Uranus?

A. Uranus always remains very close to the ecliptic, for its orbit is inclined to it by an angle of only 46′; it moves eastward for 7 months and westward for 5.

Q. 14. How many satellites has Uranus?

A. Uranus has four satellites; viz., Ariel, Umbriel, Titania and Oberon.

Q. 15. Who discovered Ariel and Umbriel?

A. Ariel and Umbriel were discovered in 1851, by Lassell.

Q. 16. How far is Ariel away from Uranus, and in what time does it move around its primary?

A. The distance of Ariel is 120,000 miles: it moves around Uranus, once in two days, 12 hours, 29 minutes.

Q. 17. What is the distance and period of Umbriel?

A. The distance is 167,000 miles; its period is 4 days, 3 hours, 28 minutes.

Q. 18. Who discovered Titania and Oberon?

A. Titania and Oberon were discovered in 1787, by W. Herschel.

Q. 19. What is the distance and period of Titania?

A. The distance of Titania is 273,000 miles; its period is 8 days, 16 hours, 56 minutes.

Q. 20. What is the distance and period of Oberon?

A. The distance of Oberon is 365,000 miles; its period is 13 days, 11 hours, 7 minutes.

Q. 21. How are the orbits of the satellites of Uranus situated?

A. The orbits all lie in one plane which is nearly prependicular to the plane of the ecliptic, making an angle of 82° with it; in this plane the satellites revolve backwards, that is from east to west.

CHAPTER XVIII.

NEPTUNE. ♆ THE SATELLITE OF NEPTUNE.

Q. 1. Which is the most remote planet of the solar system?

A Neptune is the most remote planet of the solar system?

Q. 2. What led to the discovery of Neptune?

A. It was noticed that Uranus did not exactly follow the orbit which it ought to go according to computations, but that it seemed to be disturbed by the attraction of some external planet; therefore, two young mathematicians, Adams and Leverrier, began to hunt the planet, not with telescopes, but by mathematics.

Q. 3. Did they succeed?

A Yes, both determined independently the position of the unknown planet, and Galle, of Berlin, found within half an hour's searching of the region which Leverrier had indicated the new planet, which was subsequently called Neptune, this was in 1846.

Q. 4. Had Neptune been observed before?

A. Yes, Neptune's position had been recorded on several occasions; its planetary nature was however not recognized and the planet had been put down as a small fixed star.

Q. 5. What is Neptune's distance from the sun?

A. The mean distance of Neptune is 2,792,000,000 miles.

Q. 6. In what time does this distant planet complete a revolution around the sun?

A. It completes a revolution around the sun in 164 years, 284.7 days.

Q. 7. At what rate does Neptune move in its orbit!

A. It moves with a velocity of 3.4 miles per second.

Q. 8. How much light and heat does the sun send to Neptune?

A. At Neptune's distance the sun's light and heat is only 1/900 as intense as it is at the earth.

Q. 9. How large would the sun appear at Neptune's distance?

A. At the distance of Neptune, the sun would appear too small to be seen as a disc by the eye; still it would shine very bright; the intensity of its light would be very similar to that of a large electric arc-lamp placed at the distance of a few feet.

Q. 10. What is the diameter of Neptune?

A. As with the diameter of Uranus there is still considerable discrepancy between the values obtained from the measurements by various astronomers; the number generally accepted is about 35,000 miles.

Q. 11. Assuming 35,000 miles for the diameter, what would its surface and volume be?

A. Its surface would be about 20 times and its volume 85 times that of the earth.

Q. 12. Is anything known of its rotation?

A. The time of rotation is unknown, because no well defined markings have ever been observed on Neptune.

Q. 13 How does Neptune appear in the telescope?

A. In the telescope Neptune appears like a small greenish disc.

Q. 14. Can Neptune be seen with the naked eye?

A. No, Neptune, shining about like a star of the ninth magnitude, is too faint to be visible to the naked eye, but a good opera glass will show it.

Q. 15. What is Neptune's apparent motion among the stars?

A. Neptune's motion among the stars is direct, or eastward, for $6\frac{4}{5}$ months and retrograde, or westward, for $5\frac{1}{5}$ months of the year.

Q. 16. Has Neptune any satellites?

A. Neptune has one satellite which was discovered by Lassell in 1846, a few weeks after the discovery of Neptune; it has not received a name.

Q. 17. What is this satellite's distance from Neptune, and what is its period of revolution around its primary?

A. Its distance is 221,500 miles, and its period is 5 days 21 hours 3 minutes.

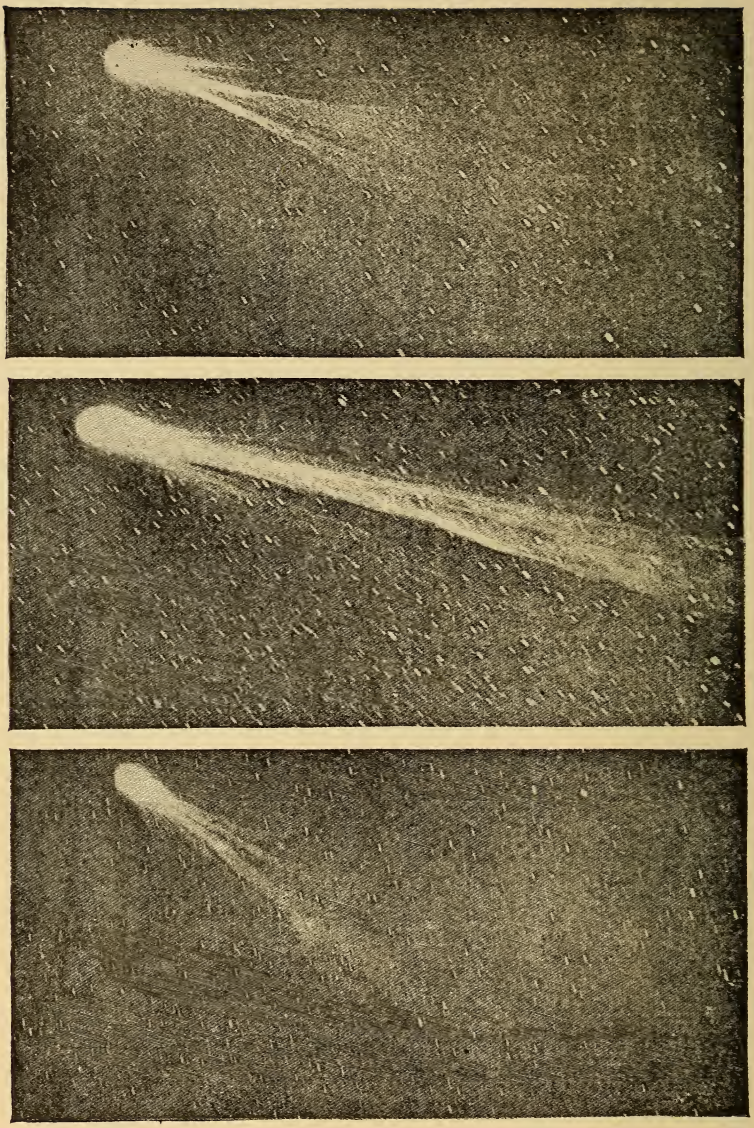

FIG. 19. SWIFT'S COMET OF 1892.

Q. 18. What is peculiar about its motion?

A. Its motion is retrograde in its orbit which is inclined to the plane of the ecliptic by an angle of not quite 35°.

CHAPTER XIX.

COMETS.

Q. 1. What are comets?

A. Comets are heavenly bodies which usually consist of a bright star-like nucleus surrounded by the coma and accompanied by a nebulous train or tail.

Q. 2. What is the appearance of the coma?

A. The coma has the appearance of a small hazy cloud.

Q. 3. Does every comet consist of a nucleus, coma, and tail?

A. No, faint comets frequently have neither nucleus nor tail.

Q. 4. Do the comets follow any law in their motions?

A. Yes, all comets move in accordance with the law of gravitation.

Q. 5. Can a comet's place in the sky be predicted?

A. As soon as a sufficient number of observations of a comet's position has been obtained, its future positions can be predicted with very great accuracy.

Q. 6. What is the form of their orbits?

A. The shape of a comet's orbit, except when modified by a planet's disturbing attraction, is always either a parabola, an hyperbola, or an ellipse.

Q. 7. When comets move in parabolic or hyperbolic orbits will they ever return?

A. Since the parabola and the hyperbola are open curves, comets which move in such orbits will probably never return.

Q. 8. When comets move in an elliptic orbit do they return?

A. Since the ellipse is a closed curve, comets which have an elliptic orbit return at regular intervals.

Q. 9. Do the orbits of the comets which move in ellipses approach the circular form, as do the orbits of the planets?

A. No; the orbits of the comets are very elongated.

Q. 10. How are the orbits of the comets placed with regard to the sun?

A. All the orbits curve around the sun and have the sun situated at the focus.

Q. 11 How are the orbits situated with regard to the ecliptic?

A. Unlike the orbits of the planets which all make but a small angle with the ecliptic, the orbits of the comets are inclined to it by angles ranging from 0° to 90°.

Q. 12. From what direction do the comets come into the solar system?

A. Comets have visited us from all parts of the heavens.

Q. 13. With what velocity do the comets move?

A. Leaving out the initial velocity which the different comets may have, the velocity depends upon their distance from the sun; the nearer they get to it the faster do they move; hence those comets which came nearest to the sun moved at that time with the greatest velocity.

Q. 14. How close do some comets get to the sun?

A. About a dozen comets have perihelion distances of less than five million miles; the Great Comet of 1882 even passed within 300,000 miles of the sun's surface.

Q. 15. How fast did this comet move then?

A. At perihelion its velocity exceeded 250 miles a second.

Q. 16. Do comets change much in appearance?

A. Yes; in general, a comet becomes brighter as it draws closer to the sun; the head, however, usually contracts when it approaches the sun, but the tail grows larger; there are frequently also other unaccountable changes, so that a comet can be identified by its orbit only.

Q. 17. What is peculiar about a comet's tail.

A. The tails of the comets are turned away from

the sun as though this body repelled them; hence when a comet moves toward the sun the tail follows, and when it recedes the tail precedes the head of the comet.

Q. 18. Is the cause of this repulsion known?

A. The explanation of this phenomenon has for a long time baffled astronomers; it has now been experimentally demonstrated that light exerts a small pressure on the bodies upon which it falls; if the particles be small enough the pressure exerted by the sun's rays will exceed the attraction of the sun for these particles and hence will be driven away from it; changes in the electrical condition of the comet very likely complicate the phenomenon.

Q. 19. Of what is the tail of a comet composed?

A. The tail is formed from the material which is ejected from the head; since the tail dissipates in space, very much like smoke from a locomotive in the air, it is evident that a comet will be gradually disintegrated by repeated visits to the sun.

Q. 20. What is the size of the heads of comets?

A. The heads of comets range from less than 10,000 miles in diameter to over 1,000,000.

Q. 21. What are the dimensions of a comet's tail?

A. In several comets the length of their tails has exceeded 100,000,000 miles; the tails are usually more or less fan-shaped and measure on their outer extremity several million miles across.

FIG. 20. NAKED-EYE VIEW OF DONATI'S COMET, OCT. 4, 1858.

Q. 22. Do the comets contain much mass?

A. Comets which have come near to the earth have had their periods changed to the extent of several weeks on account of the earth's attracting mass, but the period of the earth's revolution, *i. e.*, the year, has not been changed to the extent of one second by any comet's attracting mass; hence the conclusion, that a comet's mass as compared with that of the earth is exceedingly small.

Q. 23. Do comets shine by their own light?

A. The spectroscope shows that the great majority of comets have a spectrum identical with that of certain hydrocarbon gases when brought to incandescence; the comets therefore shine principally by their own light, although the energy which makes the gases in the comets luminous is undoubtedly, for the greater part at least, derived from the sun.

Q. 24. How many comets have been observed?

A. There are in all about 700 comets which have been recorded; of these, the orbits of about 400 have been computed.

Q. 25. How many of these 400 orbits were found to be elliptical?

A. Seventy five orbits are distinctly elliptical; the others are mostly parabolic.

Q. 26. What are the periods of the comets which move in elliptical orbits?

A. Sixty comets have periods of less than 100

years; of these, quite a few have a period of from three to eight years.

Q. 27. How are comets named?

Comets are generally designated by a letter of the alphabet, the year of the discovery, and the name of the discoverer, thus "Comet *a* 1904 (Brooks)" denotes the first comet (*b* would be the second, *c*, the third, etc.) which was discovered in 1904 and that Brooks discovered it.

Q. 28. Who was the first to recognize that certain comets are periodic?

A. Halley, a contemporary of Newton, recognized that the comet of 1682 was periodic and would return about 1758.

Q. 29. When will this comet, known as Halley's Comet, reappear again?

A. Its next appearance will be about 1911.

CHAPTER XX.

Meteors and Shooting Stars.

Q. 1. What is a meteor?

A. A meteor is a mass of matter which plunges with great velocity from outer space into the earth's atmosphere and flies through the air as a bright and fiery body?

Q. 2. How do meteors appear at night?

A. At night, they appear as balls of fire; they are

generally accompanied by a luminous train which marks out their path and which frequently remains visible long after the meteor has disappeared.

Q. 3. How do they appear by day?

A. By day the fire-ball and luminous train are not visible, but white cloud-like formations are seen in their place.

Q. 4. What features usually accompany a meteor in its flight?

A. A continuous roaring noise is produced by the meteor in its aerial flight, which is reinforced at intervals by the sharp reports of explosions by which fragments are burst off from the main body; the shocks from these explosions, together with the varying resistance of the air, make the motion of the meteor irregular, so that it seems to dart here and there at random?

Q. 5. When a meteor has fallen to the ground, what is it called then?

A. The remains of fallen meteors have been called various names, such as, aerolites, uranoliths, meteoric stones, siderites, etc.; but they are commonly referred to now as meteorites.

Q. 6. Of what are the meteorites composed?

A. Most of the meteorites are of a stony nature; the minerals which compose them resemble certain terrestial minerals of volcanic origin; a number of meteorites, however, are composed nearly entirely of iron more or less alloyed with nickel.

Q. 7. Of what size are the meteorites?

A. Of the meteorites that have been seen to fall the largest pieces found weigh about 500 pounds; of the iron masses which were not seen to fall, but which on account of their location, structure, composition, etc., are thought to be meteoric, a number weigh a few tons.

Q. 8. What is a characteristic feature of meteorites?

A. A characteristic feature of meteorites is the thin black crust which covers their entire surface, except in such places where pieces have burst away just before their fall.

Q. 9. What causes the crust?

A. The friction of the air on the meteor causes so great a heat as to make its surface incandescent and to fuse it.

Q. 10. Are the meteorites hot throughout?

A. No, the intense heat is only superficial and vanishes immediately after the fall.

Q. 11. With what velocity do meteors strike into the earth's atmosphere?

A. Meteors strike into the earth's atmosphere with an initial velocity ranging from 10 to 40 miles per second; by the time the meteor reaches the earth the speed has been reduced by the friction of the air to one or two miles per second.

Q. 12. How long is a meteor's path?

A. The length of the path depends upon the angle

at which the meteor meets the earth ; it ranges from about 50 to 500 miles.

Q. 13. What is the origin of meteors?

A. Some think that the meteors have a common origin with the planets and asteroids; others think that they are fragments which were shot off into space when the volcanoes of the moon and the earth were young and in full vigor.

Q. 14. What is the number of the meteorites?

A. Since 1800 not far from 300 newly fallen meteorites have been collected ; a vast number of meteors is of course, never seen in their flight, nor are their remains found.

Q. 15. What are shooting stars?

A. Shooting stars are, in appearance at least, meteors on a small scale.

Q. 16. How many shooting stars fall in a day?

A. It has been estimated that, if all the shooting stars that fall over the whole earth in 24 hours could be observed, their number would be somewhere between 10 and 20 millions.

Q. 17. At what heights do they appear and disappear?

A. When first seen they are at an elevation of about 75 miles, and they disappear when they are still about 50 miles above the surface of the earth.

Q. 18. With what velocity do they traverse the atmosphere?

A. During the time of visibility their average velocity is about twenty-five miles per second.

Q. 19. What is the mass of shooting stars?

A. The mass of the average shooting star probably does not amount to as much as a single grain; even the brightest shooting stars are thought to weigh less than a quarter of an ounce.

Q. 20. What is a meteoric shower?

A. When a great many shooting stars fall at any one place within a few hours, and where all the shooting stars seem to diverge from one point in the sky, the display is called a meteoric shower.

Q. 21. What is that point in which all the paths of the shooting stars, if traced backward, seem to intersect, called?

A. The point is called the radiant of the shower; in reality, it is the vanishing point of perspective for the shooting stars, since these all move in lines sensibly straight and parallel for short distances.

Q. 22. What are these meteoric swarms supposed to be?

A. Meteoric swarms are thought to be the remains of disintegrated comets or of such comets that are still undergoing disintegration.

Q. 23. What reason is there for such belief?

A. It was found that certain meteoric swarms move in orbits around the sun which are practically identical with those of certain comets.

Q. 24. Which are some of these swarms and comets?

A. The Perseids, or August meteors, move in the same path as Tuttle's comet; the Leonids, or November meteors, follow in the path of Tempel's comet of 1866, and the Andromedes pursue the same course as Biela's comet.

Q. 25. Why are meteoric showers periodic?

A. Since the meteoric swarms revolve in regular orbits around the sun, the earth can encounter them only then, when the swarms are at that point of their orbit where the earth's orbit intersects it; this happens with the Lenoids roughly every thirty-three years, around the thirteenth of November.

Q. 26. What are meteor-rings?

A. On account of the disturbing influences which act upon the meteor-swarms in the solar system, the swarms become more and more scattered and are finally strewn along their entire orbit; when the shoals of meteors have arrived at this condition, they are called meteor-rings.

Q. 27. Will a meteor-ring yield a shower every year?

A. Yes, since the meteors are scattered along their whole orbit, the earth rarely fails to pick up some each year when it crosses the orbit of the meteors; in general the display will not be as brilliant as in showers which are separated by greater intervals.

EXERCISE—The Perseids, or August Meteors, afford a convenient opportunity for observing a moderate meteoric shower and

also for finding its radiant. The Perseids move along in a very broad stream, so that it takes the earth several weeks in crossing it, and Perseid shooting stars may be seen on almost any clear night in which moonlight does not interfere during the last days of July and the first few weeks of August. The densest portion of the stream is encountered around August 10, wherefore these shooting stars have in certain places been popularly known for a long time as the "Tears of St. Lawrence." The Perseids resemble one another. They are yellowish and move with medium velocity. At that time of the year, the constellation Perseus is in the northeastern part of the sky during the evening hours. If now the paths of these yellow shooting stars be traced backwards they will all seem to radiate from a point in the constellation Perseus. A handy way to locate the radiant is to draw the observed paths of the shooting stars on a star-map or on a celestial globe.

CHAPTER XXI.

The Aurora Borealis and the Zodiacal Light.

Q. 1. What is an aurora borealis?

A. An aurora borealis, or northern lights, is a luminous appearance taking place in the upper atmosphere.

Q. 2. Of what form is the aurora?

A. Its form is very changeable, sometimes it is simply an arch of light which spans the sky near the northern horizon, frequently quivering streamers of various tints dart fitfully out from this arch toward the zenith: sometimes two, more or less, concentric arches are visible, or the aurora appears only in luminous patches; and on rare occasions the whole heavens are aglow with auroral light and streamers.

Q. 3. At what time can the aurora be seen best?

A. It is seen best when it occurs on a moonless night and when there are no clouds to interfere.

Q. 4. Do auroras occur only during the winter?

A. No, they may take place at any time of the year; in summer, however, a display is not easily noticed on account of the short nights.

Q. 5. Where are auroras most frequent?

A. Auroras become more frequent towards the frigid zones; within the torrid zone they are practically unknown.

Q. 6. What is the aurora called in the southern hemisphere?

A. It is called aurora australis, or southern lights.

Q. 7. Of what nature is the aurora?

A. The aurora is most probably of an electric nature, and is similar to the passage of an electric current through a rarified gas, which is rendered luminous by the current.

Q. 8. Are auroras more frequent in some years than in others?

A. Yes, the frequency of auroral displays grows to a maximum once in about 11.1 years, the times of minimum frequency being about half-ways between the maxima; since the frequency of sun spots varies in that same period, it is believed that the two are in some way interdependent.

Q. 9. What frequently accompanies a brilliant display of the aurora?

A. During a grand auroral display there is often a

so-called magnetic storm ; while such a storm lasts, magnetic needles vibrate restlessly to and fro, and telegraph lines, especially such as run east and west, are traversed by powerful electric currents.

Q. 10. What is the zodiacal light?

A. The zodiacal light is a disc of faint light surrounding the sun and lying along the plane of the ecliptic.

Q. 11. When is it best seen?

A. It is best seen in the evening from February to April as a triangular hazy light with its base toward the sun ; the other half is best seen in the morning during the autumnal months.

Q. 12. In what regions is it seen brightest?

A. It is seen brightest in the equatorial regions where it can be traced across the entire sky; there is a peculiar, slightly brighter diffuse spot in it which always keeps exactly opposite to the sun and which is known under the technical name of "Gegenschein" or "counter-glow."

Q. 13. What is the nature of the zodiacal light?

A. The most generally accepted opinion is, that it is the reflected sunlight from myraids of small meteoric bodies which circle around the sun in orbits more or less parallel to the plane of the ecliptic.

CHAPTER XXII.

The Fixed Stars.

Q. 1. Which are the fixed stars?

A. The fixed stars are those stars which keep the same relative positions among themselves from year to year.

Q. 2. How many of these fixed stars are visible to the naked eye?

A. There are not more than 6000 or 7000 stars which are bright enough to be distinguished by the naked eye; of these only about one third are visible at any one time.

Q. 3. What is the estimated number of fixed stars which is visible in the largest telescopes?

A. The number is estimated at 100,000,000.

Q. 4. What is the nature of the fixed stars?

A. The fixed stars are suns shining by their own light; some are larger, others are smaller, and some are many times brighter, while others emit less light, than our sun.

Q. 5. How far are the fixed stars away from the solar system?*

A. The distance of most fixed stars is so great that it has been impossible to deduce a value for it; the nearest star known so far is Alpha Centauri, which

* See Alphabet, Greek, in Appendix II.

is separated from us by a distance of 4.4 light years; *i. e.*, the light sent out by that star, is on the way 4.4 years before it reaches us.

Q. 6. What is the equivalent of a light year in miles?

A. A light year is equal to a distance of over five trillion eight hundred billion miles, or about 63,000 times the distance of the earth from the sun.

Q. 7. Are the stars absolutely fixed in their positions?

A. By no means; they are very slowly but steadily changing their apparent positions, so that after many thousand years their configurations will have been greatly altered.

Q. 8. Why is this apparent shifting so slow?

A. It is so slow on account of the vast distances which separate us from the stars; in reality, the stars are in rapid motion.

Q. 9. How great is their velocity?

A. The star called "1830 Groombridge" has a velocity exceeding 200 miles a second; the star called "61 Cygni" moves along at a speed of about 51 miles a second; and many other stars have been found to possess velocities ranging from a few miles to more than a hundred miles a second.

Q. 10 In what direction do the stars move?

A. The stars move in all directions; it has been found that certain groups of stars, as the Pleiades,

have a common motion; astronomers have therefore concluded from this and other considerations that such groups are physically related.

Q. 11. Can the velocity with which a star approaches the earth or recedes from it be measured?

A. Yes, by measuring the displacement of the lines in the spectra of the stars it has become possible to measure their "motion in the line of sight", or their "radial velocity."

Q. 12. How are the stars classified with regard to their brightness?

A. They are classified by magnitudes; the greater the number of the magnitude the fainter the star; sixth magnitude stars are just visible to the naked eye.

Q. 13. By how much do the magnitudes differ in brightness?

A. Any magnitude is about $2\frac{1}{2}$ times brighter than the next fainter magnitude.

Q. 14. What are zero and negative magnitudes?

A. Some stars are brighter than those which have been called stars of the first magnitude; zero magnitude stars are $2\frac{1}{2}$ times brighter than first magnitude stars, and stars of magnitude–1 are $2\frac{1}{2}$ brighter than zero magnitude stars. Arcturus is a star of 0.2 magnitude, and Sirius is a star of–1.4 magnitude.

Q. 15. How are stars designated?

A. Various modes of designation are in use; a

goodly number of the bright stars have proper names; the stars contained in a star-catalogue have each a number assigned them in the catalogue; in the various constellation the stars are designated by a letter of the Greek alphabet, when this is exhausted, Roman letters, and finally numbers are used.

CHAPTER XXIII.

The Constellations.

Q. 1. What is a constellation?

A. A constellation is a group of stars which represents some imaginary figure.

Q. 2. How many constellations are there?

A. There are about 67 constellations which are recognized now; 48 are of great antiquity, the remainder was introduced in modern times to take up space left unoccupied by the older constellations.

Q. 3. Where are most of the new constellations situated?

A. They are near the south pole of the heavens; the stars in this region of the sky are not visible in northern latitudes and are therefore practically unknown to people living in these regions.

Q. 4. What are circumpolar constellations?

A. They are the constellations nearest to either the north or south pole; to an observer in northern

middle latitudes the northern circumpolar stars never set, and a corresponding part of the south circumpolar sky never rises; vice versa this is true for an observer in southern middle latitudes.

Q. 5. What is the Zodiac?

A. The Zodiac is that circle of twelve constellations which lies along the ecliptic; the sun, moon, and planets always remain within the zodiac.

Q. 6. Which are the constellations of the zodiac?

A. They are: Aries, the Ram, Taurus, the Bull, Gemini, the Twins, Cancer, the Crab, Leo, the Lion, Virgo, the Virgin, Libra, the Scales, Scorpius, the Scorpion, Sagittarius, the Archer, Capricornus, the Goat, Aquarius, the Water Carrier, Pisces, the Fishes.

Q. 7. How are the constellations most easily and readily studied?

A. The simplest way is to compare the stars in the sky with a star-map; the more striking constellations like Orion, Taurus, Leo, Ursa Major, etc., will be recognized with very little difficulty.

Q. 8. How is the celestial north pole located?

A. The pole lies in a vertical plane which runs due north; in this plane the pole is elevated above the horizon by an angle equal to one's latitude; if, for instance, one lives in latitude 30° North, the pole is elevated one-third the distance between the horizon and the zenith; if the latitude is 45° North, the pole is elevated at half the distance.

Q. 9. Is the celestial south pole located in like manner?

A. Yes, the answer to the foregoing question applies word for word, if for *north* the word *south* is used.

CHAPTER XXIV.

Northern Circumpolar Constellations.

Q. 1. What star is very close to the celestial north-pole?

A. It is Polaris, the Pole-star.

Q. 2. In what constellation is the Pole-star?

A. It is in the constellation of Ursa Minor, the Little Bear.

Q. 3. Of what magnitude is Polaris?

A. Polaris is a star of 2.2 magnitude.

Q. 4. What characteristic group of stars is in the constellation Ursa Minor?

A. It is the "Little Dipper"; Polaris is at the end of the handle which is rather much bent; there are no first magnitude stars in this constellation.

Q. 5. What striking group of stars is there in the constellation Ursa Major, the Great Bear?

A. It is the "Big Dipper"; the two outer stars of the bowl are called the "Pointers" because a line

drawn through them always, though not exactly, points out the polar star.

Q. 6. Where is Draco, the Dragon?

A. The Dragon is situated in part between the Great and the Little Bear, and its head extends to the constellation Hercules.

FIG. 21—NORTHERN CIRCUMPOLAR CONSTELLATIONS.

Q. 7. Is this constellation easily traced?

A. Yes, a quadrilateral of stars forms the head, and a sinuous line of stars marks out the body.

Q. 8. Is there any remarkable star in this constellation?

A. Thuban, or Alpha Draconis was the polar star 4,000 years ago.

Q. 9. Where is the constellation Cepheus?

A. It is between Draco and Ursa Minor on one side and Cassiopeia on the other; this constellation contains nothing of especial interest.

Q. 10. How can the constellation Cassiopeia be found?

A. This constellation is on the opposite side of the pole from the "Dipper" and just as far from it; the bright zigzag line of stars makes it an easy object for identification.

Q. 11. What other circumpolar constellations are there?

A. Camelopardalis, the Giraffe, lies between the pole, Cassiopeia and the Great Bear; Lynx is also partly circumpolar; there are no bright stars in these constellations.

CHAPTER XXV.

Equatorial and Adjoining Constellations.

Q. 1. At what time of the year is Andromeda on the meridian at nine o'clock in the evening?

A. In the early part of December.

Q. 2. How may this constellation be recognized?

A. It may be recognized by the nearly straight line made by three stars of the second magnitude, which stretches from Pegasus to Perseus.

Q. 3. When is Perseus on the meridian at nine o'clock in the evening?

A. Perseus is on the meridian at 9 o'clock in the evening during the latter part of December.

Q. 4. By what group of stars may Perseus be known?

A. The so-called "Segment of Perseus" which is a curved line of stars running along the "Milky Way" and which extends from Cassiopeia to Auriga points out this constellation.

FIG. 22—ARIES AND ADJOINING CONSTELLATIONS.

Q. 5. Where is Pegasus?

A. Pegasus adjoins Andromeda and Pisces; it comes to the meridian* at nine o'clock in the evening during the latter part of October.

Q. 6. What characteristic grouping of stars is there in Pegasus?

A. It is the "Great Square of Pegasus"; this square together with the bright stars of Andromeda forms a huge figure which resembles the shape of the "Big Dipper" very much.

Q. 7. What constellation is immediately south of Andromeda?

A. Pisces, the Fishes, are south of Andromeda; there are no bright stars in this constellation; the vernal equinox, *i. e.*, one of the two points where the celestial equator and the ecliptic intersect, lies in this constellation.

Q. 8. Where is Aries, the Ram?

A. Aries is east of Pisces; a short broken line made by three stars, of which the upper one is the brightest, is easily recognized; Triangulum, the Triangle, is a small constellation of stars arranged in triangular shape and is situated between Andromeda and Aries.

* The time of arrival on the meridian of a constellation is necessarily stated quite loosely; from now on, the hour of 9 o'clock in the evening will be assumed when the approximate time of culmination (*i e.*; the coming to the meridian) of a constellation is given.

Q. 9. What constellation is east of Aries?

A. Taurus, the Bull is east of Aries; the V-shaped Hyades and the Pleiades, frequently called the "Seven Sisters", make Taurus an easy object for beginners; this constellation is on the meridian during January.

FIG. 23—ORION AND HIS DOGS.

Q. 10. What bright star is in the Hyades?

A. It is the fiery star Aldebaran; this star is exactly of the first magnitude.

Q. 11. Where is the constellation Auriga, the Charioteer?

A. Auriga is north of Taurus and Gemini; it con-

tains the 0.1 magnitude star Capella which has a bright yellow color; a small triangle of stars near by are called the Hoedi, or Kids.

Q. 12. What constellation is east of Taurus?

A. Gemini, the Twins, is east of Taurus; Castor and Pollux the two brightest stars of this constellation are both between the first and second magnitudes; Pollux comes to the meridian 11 minutes after Castor's culmination; the evening culminations occur in the early part of March.

Q. 13. Where is Cetus, the Whale?

A. Cetus is just south of Pisces and Aries; an irregular pentagon of stars south of Aries marks the head of this huge monster.

Q. 14. When has the glittering Orion its evening culminations?

A. Orion comes to the meridian during the latter part of January; it adjoins Taurus on the southeast.

Q. 15. Which are the principal configurations of stars in this constellation?

A. Four bright stars form a large quadrilateral; within this figure runs a diagonal line, the Belt of Orion, consisting of three second magnitude stars; an irregular line of smaller stars extends from the belt southward; this constellation, once learned, cannot be mistaken for anything else.

Q. 16. What names have been given to the Belt of Orion?

A. In the "Book of Job" it is called the "Bands of

Orion"; the terms "Jakob's Rod" and "Ell and Yard" are also in use.

Q. 17. What constellations are south of Orion?

A. Lepus, the Hare, indicated by a small quadrilateral of third and fourth magnitude stars, is just south of Orion; still farther south is Columba, the Dove; to the southwest of Orion, the river Eridanus meanders over the celestial plains.

Q. 18. What constellations accompany the hunter Orion to the east and southeast?

A. They are Canis Minor, the Little Dog, and Canis Major, the Great Dog; Procyon is a bright star of the 0.5 magnitude in Canis Minor, whereas Sirius, the "dog-star" in Canis Major is of the —1.4 magnitude; Sirius is the brightest fixed star in the heavens.

Q. 19. Where is Cancer, the Crab?

A. Cancer is east of Gemini; it comes to the meridan during March; a little quadrangle (whose two western stars are however quite faint) with a hazy spot in it, the star-cluster Praesepe, mark out this constellation sufficiently.

Q. 20. What constellation is east of Cancer?

A. It is Leo, the Lion; the evening culminations occur during April; this constellation is easily recognized by the "Sickle" and the triangle which the two stars Beta and Delta Leonis make with Regulus in the handle of the sickle.

Q. 21. Where is the constellation Virgo, the Virgin?

A. This constellation lies east of Leo; it comes to the meridian in the latter part of May; Spica, a lonely situated bright star of the 1.1 magnitude indicates where the constellation may be found.

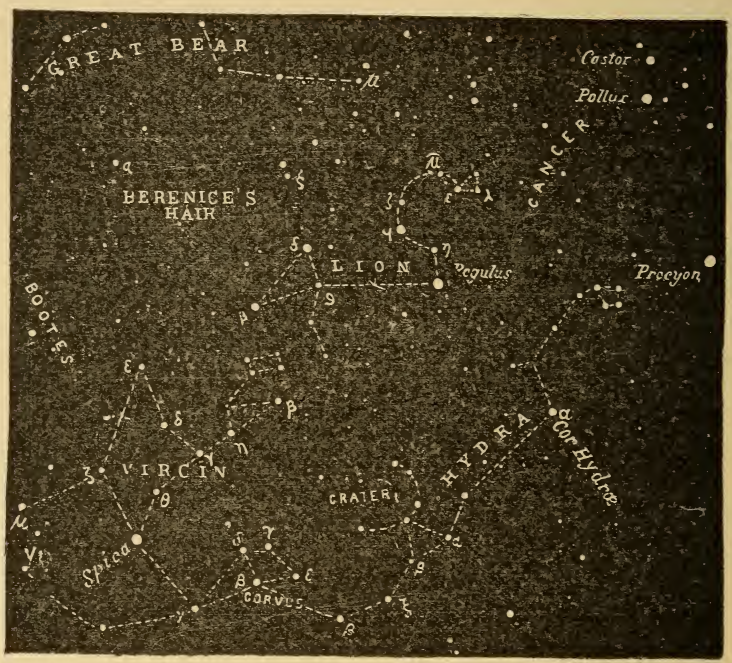

FIG. 24—THE LION RAMPANT IN THE SKIES.

Q. 22. What constellation stretches from south of Cancer beyond Virgo?

A. It is Hydra which has its head indicated by a group of small stars south of Cancer; the rest of the constellation may be traced by means of the irregularly

curved and broken line of stars that extends from the head to nearly up to Scorpius.

Q. 23. What other constellations are in this region of the sky?

A. Monoceros, the Unicorn, fills up the gap between Canis Major and Canis Minor; Sextans, the Sextant, is between Leo and Hydra; adjoining Sextans at the southeast is Crater, the Cup, indicated by a pretty semicircle of six small stars; just east of Crater is Corvus, the Crow, which is marked out by a small quadrilateral of stars; south of Monoceros and east of Canis Major is a part of the huge southern constellation Argo Navis, the Ship Argo; adjoining this portion of Argo on the east is Pyxis Nautica, the Mariner's Campass, and east of this is Antlia Pneumatica, the Air-pump; both are modern constellations merely designed to take up the spaces left between the older constellations.

Q. 24. What constellations are north of Leo and Virgo?

A. Between Leo and Ursa Major is Leo Minor, the Little Lion; just south of the handle of the "Big Dipper are Canes Venatici, the Hounds; Cor Caroli, the brightest star of this constellation, is easily located; between Canes Venatici and Virgo is the constellation Coma Barenicis, the Hair of Berenice; a line drawn from Cor Caroli to Denebola, the bright star farthest east in Leo, passes through the fine star cluster of Coma Berenicis.

Q. 25. Where is the constellation Bootes?

A. Bootes is east of Canes a Venatici and Coma Berenicis, and reaches from Ursa Major down to Virgo; it comes to the meridian in June; Arcturus, a star of ruddy hue, and one of the brightest fixed stars, is in this constellation.

FIG. 25—HERCULES, BOOTES, AND QUEEN BERENICE'S HAIR.

Q. 26. What small, but very pretty, constellation borders upon Bootes at the east?

A. This pretty constellation is Corona Borealis, the Northern Crown, which is very readily recognized by a semicircle of six stars; the open part of the figure lies toward the northeast.

Q. 27. What constellation is south of Corona?

A. It is Serpens, the Serpent; a sinuous line of stars

leads to Ophiuchus,* the Serpent-bearer; a lozenge-shaped figure, made by stars in Serpens and Ophiuchus, is one of the most characteristic groups of stars which strike the eye on a summer evening.

FIG. 26—MIDSUMMER EVENING CONSTELLATIONS.

Q. 28. What constellations are south of the ones just mentioned?

A. They are Libra, the Scales, and Scorpius, the Scorpion; the latter is very easily recognized by its curved line of bright stars, among which blazes the

*Ophiuchus is also called Serpentarius.

fiery Antares, the rival of Mars in color and brightness; this star is of the 1.2 magnitude.

Q. 29. What constellation is north of Ophiuchus?

A. It is Hercules, which extends as far north as Draco; Alpha of Hercules and Alpha of Ophiuchus, the brightest stars of their constellations, are separated only by a short distance and occupy a rather isolated position.

Q. 30. What constellation is east of Hercules and south of Draco?

A. Lyra, the Lyre, occupies this position; it contains the bluish-white star Vega of the 0.2 magnitude, near which is a parallelogram of fainter stars; Lyra culminates in August.

Q. 31. Is there anything noteworthy regarding Vega?

A. Yes, on account of the precession of the equinoxes, the celestial pole describes a circle in the heavens around the pole of the ecliptic once in about 25,800 years; 12,000 years hence the celestial north pole will have moved close to Vega, which will then be the pole-star.

Q. 32. Where is Cygnus, the Swan?

A. Cygnus is due east of Lyra; it is readily recognized by the great cross made by its brighest stars; 61 Cygni, a double star, and the apex of a small triangle in the northeast quarter of the cross, is one of our nearest neighbors; the light of this star

is on the way 8.1 years before it reaches us; Cygnus culminates in September.

Q. 33. What constellations are adjacent to Cygnus?

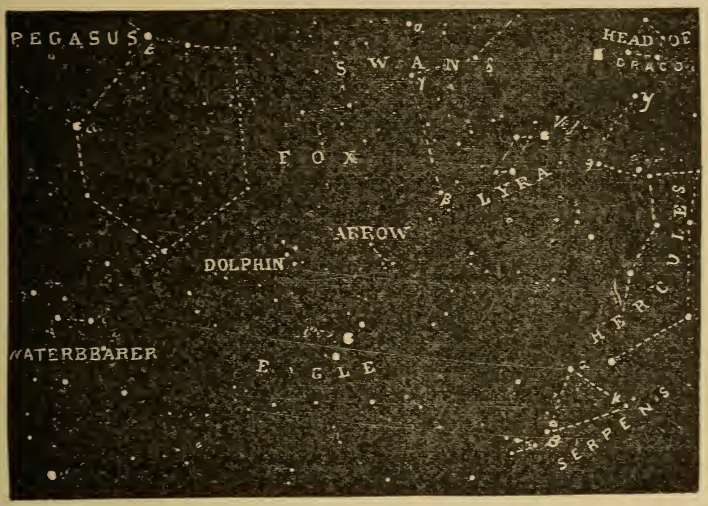

FIG. 27—THE SWAN, THE EAGLE, AND THE DOLPHIN.

A. Lacerta, the Lizard, fills up the space between Cygnus and Andromeda; Vulpecula and Anser, the Fox and Goose, are immediately south of Cygnus; south of Vulpecula lies the small Sagitta, the Arrow, which has on its east side Delphinus, the Dolphin; a diamond shaped group of stars, frequently called "Jobs's Coffin" is a characteristic mark of the Dolphin.

Q. 34. Where is Aquila, the Eagle?

A. Aquila is south of Sagitta; three stars in a straight line of which the middle star, Altair, is the

brightest, being of the 0.9 magnitude, make the constellation an easy object for identification.

Q. 35. What other constellations are in this neighborhood?

A. Equuleus, the Colt, a small and insignificant constellation adjoins Pegasus on the southwestern corner; parts of Aquila had been appropriated for special constellations, but their names are meritedly falling into disuse.

Q. 36. Where is Sagittarius?

A. Sagittarius, the Archer, is the next zodiacal constellation towards the east after Scorpius, the little "Milk Dipper" is its most striking group of stars.

Q. 37. Where is Capricornus, the Goat?

A. Capricorn is east of Sagittarius; the pretty naked-eye double-star in Capricorn readily catches the eye in the autumn evenings; this constellation culminates in September.

Q. 38. What constellation takes up the space between Capricornus and Pisces?

A. It is Aquarius, the Water-bearer; a little Y of small stars is the principal configuration; Piscis Austrinus, the Southern Fish, which contains the bright star Fomalhaut of the 1.3 magnitude, is south of Aquarius.

CHAPTER XXVI.

Southern Circumpolar and Neighboring Constellations.

Q. 1. Is there any bright star near the celestial south pole?

A. There is no conspicuous star very near the south pole; but the southern sky is rich in constellations of surpassing beauty and interest.

Q. 2. How do the constellations appear to an observer in the southern hemisphere?

A. The constellations appear reversed to him with reference to the horizon, *i. e.*, what a northern observer calls *up*, a southern observer calls *down*; thus, the two stars which in north latitudes form the base of the parallelogram of Orion, form here the upper side, and Sirius though, of course, still south of Orion is above it; for a northern observer the north pole of the heavens is permanently above the horizon and the south pole as much below it, whilst the opposite is true for the southern observer.

Q. 3. What constellation is south of Antlia and Pyxis mentioned in the preceding chapter?

A. It is the ship Argo which extends along the declination circle passing through it for nearly one-fourth the circumference of this circle.

Q. 4. What bright star is there in Argo.

A. Canopus is of the -0.8 magnitude and is the

second brightest fixed star in the heavens; it comes about 20 minutes earlier to the meridian than Sirius, the brightest star, but it is over 36° farther south.

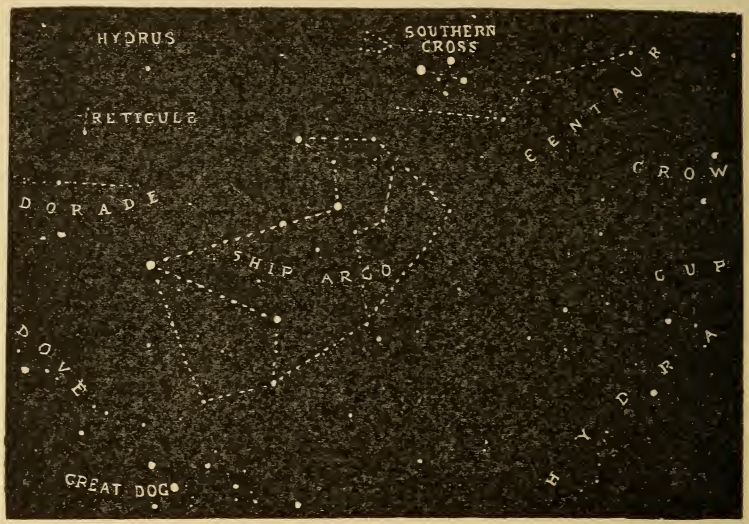

FIG. 28—THE SOUTHERN CONSTELLATIONS.

Q. 5. What constellation is east of Argo?

A. Centaurus, the Centaur, is east of Argo; Alpha of Centaurus which is a binary star and one of the brightest stars in the heavens is, as has been remarked before, our nearest neighbor.

Q. 6. What constellation is bounded by Centaurus on the east, west and north?

A. The beautiful constellation Crux, the Southern Cross, is situated here; the dark places, called the coal sacks, in the Milky Way which passes through this constellation heighten the splendor of

the closely set stars in the cross; it culminates in May.

Q. 7. Is the cross only visible in the southern hemisphere?

A. Since the Cross is more than 25° away from the south pole of the heavens, it follows, that the Cross will appear above the horizon for this distance north of the equator; for people living near the tropic of Cancer, the Cross is deprived of much of its beauty for the reason that it appears only just a little above the southern horizon.

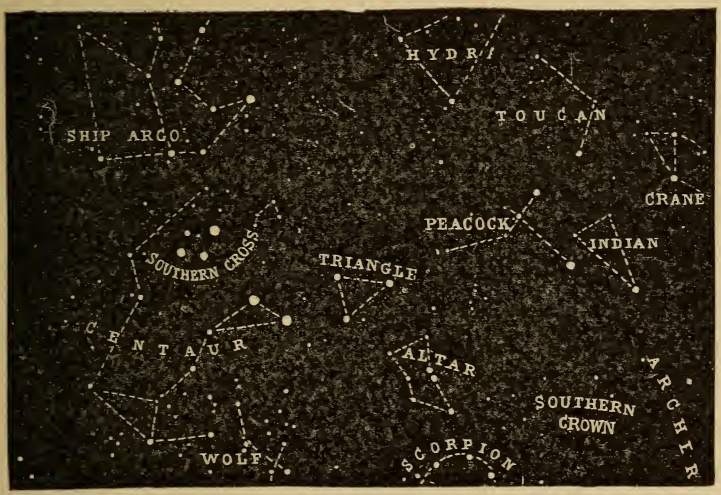

FIG. 29—SOUTHERN CIRCUMPOLAR CONSTELLATIONS.

Q. 8. What use do people of southern countries make of the cross?

A. The Cross stands upright when it passes

through the meridian, before and after passage the Cross is inclined; knowing what inclination the Cross has at different seasons for a fixed hour, the inhabitants of these regions use it as a means whereby to tell the time.

Q. 9. What constellation is on the opposite side of the pole from Crux?

A. Toucana, the Toucan, is on the opposite side of the south pole; north of Toucana are Phoenix and Grus, the Crane; between Centaurus and Grus lie a number of constellations, such as Circinus, the Compass, Lupus, the Wolf, Triangulum Australe, the Southern Triangle, Altare, the Altar, Pavo, the Peacock, Indus, the Indian, and others; the order of succession of the above-named constellations is more or less from west to east; Altare culminates in the latter part of July, Indus in September, and Phoenix and Toucana in November.

Q. 10. What very interesting object lies on the southeastern confines of Toucana, but is mostly within the adjacent constellation Hydrus, the Water-Snake?

A. This interesting object is Nubecula Minor, the Lesser Magellanic Cloud, which is composed of a rich aggregation of stars, star-clusters, and nebulas; it comprises an area of 10 square degrees.

Q. 11. Where is Nubecula Major, the Greater Magellanic Cloud?

A. Nubecula Major lies partly in Dorado but mostly in Mons Mensa, the Table-land, which is south

of Dorado and extends to within 5° of the pole; Nubecula Major, which has the same composition as Nubecula Minor but is brighter than it, comprises an area of 42 square degrees and is at a distance of about 20° from the pole; a plane through Orion and the south pole passes through Nubecula Major.

Q. 12. How far south does Eridanus extend?

A. Eridanus extends from Taurus at the equator south to 32° from the pole; at its southern extremity is Achernar a bright star of the 0.4 magnitude.

Q. 13. In what constellation is the south pole of the heavens situated?

A. The south pole is in the constellation Octans, the Octant.

EXERCISE. On some clear evening when moonlight does not interfere, select a place which is screened from strong artificial illumination and which affords an unobstructed view of at least a considerable portion of the sky. According to the season and the evening hour different constellations will be on the meridian. With the aid of the preceding chapters and the star-maps it ought to be an easy matter to identifiy them. This process repeated at different times of the year will soon bring on an acquaintance with with the principal constellations visible in your latitude. An ordinary opera glass will be of assistance, especially for such as have weak eyes.

CHAPTER XXVII.

TEMPORARY STARS AND VARIBLE STARS.

Q. 1. What are temporary stars?

A. Temporary stars are such stars that blaze up suddenly, some of them becoming exceedingly bright, and then gradually fade away.

Q. 2. Do temporary stars disappear entirely?

A. A number still persist as faint stars, but others have disappeared entirely from view.

Q. 3. How many temporary stars are there?

A. The number of temporary stars is about 40; the last bright temporary star is Nova Persei which was discovered by Anderson, Feb. 21, 1901.

Q. 4. What causes these stars to blaze up and then fade?

A. Different explanations have been advanced, but no one can be considered as universally accepted; it has been suggested that the star suffers some kind of explosion; another explanation says that two celestial bodies got into collision; still another, and, perhaps, the true explanation has it, that a star either very faint, or already extinct has encountered a nebula on its path.

Q. 5. What are variable stars?

A. Variable stars are such as suffer a change in brightness.

Q. 6. How are variable stars classified?

A. Variable stars are classified as irregular, when they alternately become brighter and darker without any apparent law; as periodic, when the changes in brightness occur during fixed intervals; and as continuous, when a star slowly but continuously becomes either brighter or darker; of this last kind perhaps a dozen instances are known.

Q. 7. Which is the most notable star that varies in brightness without regularity?

A. The star Eta in Argo (not visible in the United States) was in 1843 second in brightness only to Sirius, since then with irregular fluctuations it has dwindled down to the seventh magnitude; a number of other bright stars show irregularities, but the change in brightness is very much smaller.

Q. 8. How are the periodically variable stars subdivided?

A. They are subdivided into long-period variables, short-period variables, and variables of the Algol type.

Q. 9. Which is a typical star of the long-period variables?

A. Mira ("the Wonderful"), which is the star designated by the Greek letter Omicron in the constellation Cetus, is a long-period variable; during most of the time it is too faint to be seen with the unaided eye, but once in about eleven months it runs up to the fourth or even to the second magnitude and then decreases more slowly than it increased; Fabricius discovered its variability in 1596.

Q. 10. Do many variables belong to this class?

A. Yes; most of the variable stars belong to this class; a great many of these are reddish in color.

Q. 11. How do the short period variables behave?

A. In these the brightness is never constant for a longer period of time, but the star is always either

getting brighter or darker; the periods of these stars range from less than a day to three weeks; Eta Aquilae and Beta Lyrae are typical stars of this class.

Q. 12. To what are these changes thought to be due?

A. It is believed that one or more companions revolving around the main star cause these changes.

Q. 13. How do the variables of the Algol type behave?

A. These remain of constant magnitude, except at regular intervals they become much fainter within the space of a few hours, and then just as rapidly recover their former brightness; Algol, Beta Persei, thus shines mostly as a star of the second magnitude, but it sinks down to the fourth magnitude once every 2 days, 20 hours, 49 minutes; it looses and regains its brightness in a little over 9 hours.

Q. 14. What causes this variation?

A. It was suggested more than a century ago that variations in brightness as exhibited by Algol might be caused by the regular interposition of a dark companion which revolves around its primary; the shifting of the lines in the spectra of these stars has shown this explanation to be the true one; in some cases both stars are bright, but so close are they together optically, (actually they are millions of miles apart) that not even a large telescope will separate them; evidently, if their orbital plane lies in the line of sight, they will send us less light when one is in front of the other than when both are in view.

Q. 15. By what method are most variable stars discovered nowadays?

A. By means of photography; the size of the image of a star on a photographic plate, exposed a definite length of time, is nearly proportional to its brightness; if now the same stars are photographed at different times, any change in brightness will be indicated by a corresponding size of image.

Q. 16. What are variable star-clusters?

A. Examination of photographs of star-clusters has brought out the fact that in certain clusters a large number of stars is variable, *e. g.*, the cluster called Messier 3, which is in Canes Venatici, contains 132 variables; Omega Centauri has 122; 33 variable stars have been detected in cluster Messier 4, which is a little way west of Antares in Scorpius.

EXERCISE—Try to ascertain the time at which Algol is at minimum. It will be interesting to note how much fainter it is then, than usual. If you have leisure to watch it, you will find that in three and one-half hours it recovers its regular brightness. Observation of variable stars is a field of work well suited for amateurs, because a great deal can be done without any instrumental equipment whatsoever, or which requires, at the highest, the use of an ordinary opera glass.

CHAPTER XXVIII.

DOUBLE AND MULTIPLE STARS.

Q. 1. What are double stars?

A. Double stars are such stars which to the naked eye appear as single stars, but which, when viewed

with a telescope, are found to be composed of two stars in close proximity.

Q. 2. What are naked-eye double stars?

A. Stars which can be easily seen as double by the unaided eye, such as Theta Tauri, Alpha Capricorni and Mizar with its companion Alcor, which is the middle star in the handle of the Big Dipper, are called naked-eye doubles.

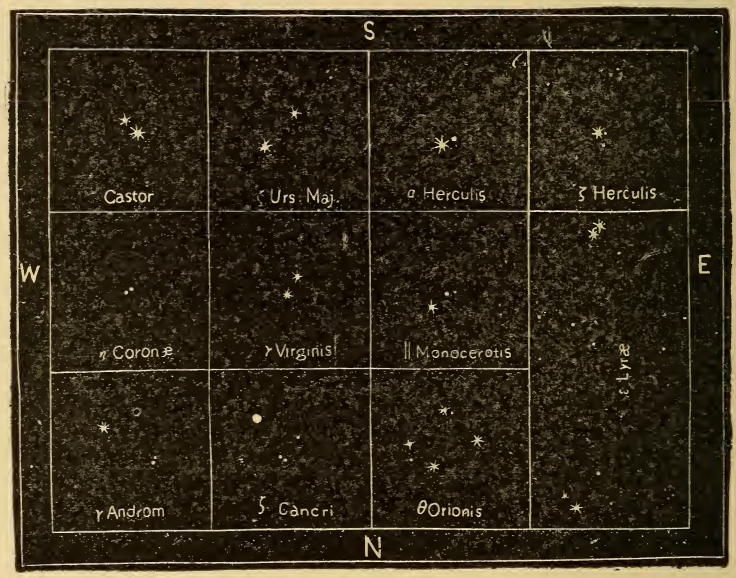

FIG. 30. DOUBLE AND MULTIPLE STARS.

Q. 3. How are double stars classified?

A. They are classified as optically and physically double.

Q. 4. What are optically double stars?

A. Optically double stars are those which simply are in line with each other and where one is much farther away than the other; the pole-star has a small star of the ninth magnitude near it which is in the same direction as the pole-star, but is far beyond it.

Q. 5. What are physically double stars?

A. Physically double stars are those which move around a common center of gravity and move in elliptical orbits; these double stars are usually called *binaries.*

Q. 6. Are there many binary stars?

A. The number of binary stars already discovered is quite large and the list is continuously increasing.

Q. 7. What are the periods of revolution of these binaries?

A. There is a great range in the length of their periods, extending from a small number of years to several hundred; Sirius, *e.g.*, has a period of 49 years, its mass being 3.13 times that of the sun, and Alpha Centauri has a period of 81 years, its mass being twice that of the sun.

Q. 8. What are spectroscopic binaries?

A. Spectroscopic binaries are stars which cannot be shown as double by any telescope; the spectroscope, however, gives conclusive evidence that the light of such stars comes from two distinct sources which alternately approach and recede from us as they revolve in their orbit.

Q. 9. Are there many spectroscopic binaries?

A. About every twelfth star of the brighter ones so far examined has proved to be a spectroscopic binary.

Q. 10. What are the periods and the orbital velocities of the spectroscopic binaries?

A. The periods range from a day to several years and their orbital velocities reach several hundred miles a second; Beta Aurigae, for instance, has a period of four days, a velocity of about 150 miles a second, a mass more than twice that of the sun, and the orbit in which the two components move is about 8,000,000 miles in diameter.

Q. 11. What are multiple stars?

A. There is a considerable number of cases where three or more stars form a physically connected system, these are called multiple stars; besides these systems, there is also a goodly number of visually multiple stars.

Q. 12. Are the components of binary multiple systems of the same mass and brightness?

A. Sometimes the components are very similar, but frequently there is great diversity in size and brightness; in a number of cases a component does not emit any light at all.

Q. 13. Are there any differences in color in these systems?

A. Many systems present striking contrasts in color; it is remarkable that in the binaries the smaller star is always bluer than the larger.

FIG. 31. THE GREAT CLUSTER IN HERCULES.

CHAPTER XXIX.

The Galaxy, Star-Clusters And Nebulae.

Q. 1. What is the galaxy, or Milky Way?

A. The galaxy is a luminous belt of varying width and brightness which surrounds the whole heavens; from Cygnus to Scorpius it divides up into two streams which are nearly parallel; it also contains blank holes and openings and is in several places crossed by dark bands.

Q. 2. What causes the sheen of the galaxy?

A. This is caused by the combined light of a vast multitude of faint fixed stars which constitute the galaxy.

Q. 3. How are the stars distributed in the heavens?

A. They are densely crowded in the Milky Way; on either side the number decreases very rapidly; a telescope showing in its field of view 122 stars in the galaxy shows but ten stars at a distance of 90° from the galaxy.

Q. 4. What are star-clusters?

A. Star-clusters consist of a multitude of stars grouped in a small space; a cluster may contain from a hundred to many thousand stars.

Q. 5. Which are some of the clusters visible to the naked eye?

A. The Pleiades in Taurus, the Praesepe in Cancer,

the double group in the sword-handle of Perseus, and the magnificent aggregation of stars in the southern constellation Toucan are clusters visible to the naked eye, to which they appear, the Pleiades excepted, as hazy spots; a small telescope, or even a good opera glass will, however, show them as real clusters.

Q. 6. What are nebulae?

A. Nebulae are faintly shining patches in the sky which the spectroscope has shown to consist of matter in the gaseous state in various stages of condensation.

Q. 7. Are there many nebulae?

A. Yes, over 10,000 have already been discovered, mainly by photography, but only a very few are visible to the naked eye.

Q. 8. How are the nebulae distributed in the heavens?

A. Their distribution is opposite to that of the stars; only a few are in or near the Milky Way, but their number increases rapidly as the distance from the galaxy increases.

Q. 9. Which are a few of the most notable nebulae?

A. The Great Nebula in Andromeda, the Great Nebula in Orion, the Ring Nebula in Lyra, the Dumb-bell Nebula in Vulpecula, the Spiral Nebula in Canes Venatici and the Trifid Nebula in Sagittarius are some of the most noted nebulae; the first two are visible to the naked eye.

FIG. 32. THE GREAT NEBULA IN ANDROMEDA.

EXERCISE.—Count the stars in the Pleiades, of which six are very easily seen. Thereupon look at the group with an opera glass and you will notice that a great many more stars have become visible. Fix in your mind the positions of some of the brighter stars which you did however not see with the naked eye before, and try to see them without the opera glass. It is almost certain that you can now easily see one or several stars more because vou know beforehand where and what to look for.

CHAPTER XXX.

THE NEBULAR THEORY.

Q. 1. Can natural science account for the existence of the universe?

A. No; natural science is absolutely unable to account for the existence of the universe?

Q. 2. Why is natural science unable to account for the existence of the universe?

A. Because natural science is based on the laws and the order which are observed in things already existing and endowed with their various properties; natural science, therefore, postulates matter already in existence, and, just as little as matter can produce itself, can natural science account for the existence of matter.

Q. 3. How, then, can the existence of the universe be accounted for?

A. The only rational way is to hold, that an infinite and ever-existent Being, Almighty God, has created matter and has endowed it with its various properties.

Q. 4. Is it within the province of natural science to

investigate the successive stages of development through which matter has passed after being called into existence?

A. Since change and development is ever going on according to fixed laws, and since these laws are held to have been in existence as long as the matter existed to which they apply, it follows that it is within the domain of science to trace things back to their beginnings as far as this may be possible.

Q. 5. What theory tries to account for the present arrangement of the solar system.

A. It is the Kant-Laplace Nebular Theory.

Q. 6. What does the Nebular Theory teach?

A. It teaches that at one time the material concentrated in the sun and its attendant bodies, was distributed as a nebula over a vast space, the nebula, as a whole, having a resultant motion of rotation; under the action of its own gravitation it began to concentrate and different portions separated at intervals from the main mass to form the planets; from these abandoned portions, in the process of further concentration, smaller masses would again separate to form the satellites of the planets until, finally, the solar system, as we know it, was evolved.

Q. 7. Was any heat developed while contraction was going on?

A. It is a law of nature that the temperature of a gaseous nebula continually rises while contracting and even after it has condensed so much as to be no longer

gaseous, it still gives off great quantities of heat; Helmholtz has shown that the contraction of the sun is the probable source of nearly all the sun's heat.

Q. 8. Are there any reasons which make the nebular theory probable.

A. Yes, there are a number of reasons which render the nebular theory probable; such are, for instance, the signs of past igneous action on the moon, the present physical conditions of the planets and their common direction of rotation and revolution, the nebulosity surrounding many stars, the similarity between the spectra of certain kinds of nebulae and stars, the antithetical distribution of the stars and the nebulae in space, etc.

Q. 9. If the solar system was evolved according to the nebular theory, how long would the sun's heat last?

A. It is believed that within 5 to 10 million years the sun would begin to cool off rapidly and cease to be a source of light and heat; the solar system began its history perhaps not more than 20 million years ago.

Q. 10. Did the stars also evolve from nebular masses?

A. The stars, it is assumed, are the products of evolution; the white and bluish stars are the youngest and hottest, whereas the reddish stars are thought to be approaching extinction.

APPENDIX I.

A Few Simple Problems on the Celestial Globe.

Q. 1. What is a celestial globe?

A. A celestial globe is a sphere on whose surface the constellations are represented together with the principal circles by means of which the positions of celestial objects are defined.*

Q. 2. Where is the earth and, therefore, the observer supposed to be situated?

A. The earth is supposed to be situated at the centre, its axis coinciding with the axis of the globe and its equator lying in the plane of the celestial equator.

Problem I.

To determine which constellations never set and which never rise at any one place.

Rule. Elevate the pole (the north pole if you live north of the equator, the south pole if you live south of it) above the horizon circle by the number of degrees of your latitude; the portion around the elevated pole which does not go below the horizon circle, as you turn the globe, never sets and the corresponding portion around the depressed pole never rises for that particular latitude.

Exercise.

On the equator the latitude is zero; by the rule the poles for an observer there must both lie in the horizon, hence all the stars rise and set at the equator. Show that on the equator the sun rises and sets at six o'clock throughout the year. At the poles the latitude

* It is assumed that the globe is provided with a graduated meridan circle in which the axis may be given any inclination, and with a horizontal circle to represent the horizon.

is 90°, hence by the rule the axis of the globe is perpendicular to th horizon circle and all the stars move in circles parallel to the hori zon. One half of the heavens therefore never sets and the other half never rises for an observer at the poles. Show that at the poles the sun is six months above the horizon and six months below it.

Problem II.

To find the right ascension of the sun or of a star.

RULE. Bring the sun's place in the ecliptic or the star under the meridan circle; then the number of hours * counting from the vernal equinox eastward along the equator, or equinoctial, up to the meridan circle is the required right ascension.

* One hour equals 15 degrees.
One minute equals 15 minutes of arc.
One second equals 15 seconds of arc.

Exercise.

Show that the sun's right ascension is:

0	hours on	March	21st	(*For 1906*)
4	"	May	23d	
6	"	June	21st	
12	"	Sept.	23d	
18	"	Dec.	23d	

Show that the right ascension of:

Aldebaran (Alpha Tauri) is 4 hours, 31 minutes
Sirius (Alpha Canis Majoris) is 6 hours, 40 minutes
Arcturus (Alpha Bootis) is 14 hours, 11 minutes
Altair (Alpha Aquilae) is 19 hours, 46 minutes.

Problem III.

To find the declination of the sun or a star.

RULE. Bring the sun's place in the ecliptic or the star under the meridian circle; then the difference in degrees measured along the meridian circle between the equator and the sun or star is the required declination; when the sun or star is north of the equator the declination is positive, when south of the equator, it is negative.

EXAMPLE. What is the declination of Vega (Alpha Lyrae) when the reading of the meridian at Vega is 80°, 42′ and where the equator crosses it 50° ? The declination is 80° 42′-50°= + 38° 42′.

Exercise.

The sun's place is always in the ecliptic. Show that the sun's greatest declination north or south of the equator is $23\frac{1}{2}°$ and that this occurs at the solstices in June and December; likewise show that the sun's declination is zero, *i. e.*, the sun crosses the equator at the equinoxes, in March and September.

Show that the declination of:

Aldebaran is $+16° 19'$
Sirius " $-16° 35'$
Arcturus " $+19° 40'$
Altair " $+ 8° 37'$

Problem IV.

The right ascension and declination of a heavenly body being given, to find its place on the globe.

RULE. Take the given right ascension in the equator and bring this point under the meridian circle, then take a distance north or south of the equator along the meridian circle equal to the given declination; the position reached is the place required.

EXAMPLE. What is the star whose right ascension is 22 hours, 52 minutes and whose declination is $-30° 7'$? The star is Fomalhaut (Alpha Piscis Australis) in the Southern Fish.

Exercise.

Locate and name the stars whose right ascensions and declinations are as follows:

Right Ascension.	*Declination.*
1 hour, 25 minutes	$+88° 48'$
4 hours, 30 "	$+16° 19'$
5 " 10 "	$- 8° 19'$
6 " 41 "	$-16° 35'$
10 " 3 "	$+12° 26'$
14 " 11 "	$+19° 40'$
16 " 23 "	$-26° 13'$
19 " 46 "	$+ 8° 37'$

APPENDIX II.

Astronomical Terms.

Aberration of light is an apparent displacement of a star, owing to the velocity of light combined with the velocity of the earth in its orbit.

Aerolite. see Meteorite.

Almanac, Nautical, published by U. S. Government, contains current astronomical phenomena and data.

Alphabet Greek:

Letters.	Names.	Letters	Names.	Letters	Names
A, α	Alpha,	I, ι	Iota,	P, ρ	Rho,
B, β	Beta,	K, κ	Kappa,	Σ, σ ς	Sigma,
Γ, γ	Gamma,	Λ, λ	Lambda,	T, τ	Tau,
Δ, δ	Delta,	M, μ	Mu,	Υ, υ	Upsilon,
E, ϵ	Epsilon,	N, ν	Nu,	Φ, ϕ	Phi,
Z, ζ	Zeta,	Ξ, ξ	Xi,	X, χ	Chi,
H, η	Eta,	O, o	Omicron,	Ψ, ψ	Psi,
Θ, θ	Theta,	Π, π	Pi,	Ω, ω	Omega.

Altitude is the elevation of a celestial body above the horizon.

Amplitude is the angular distance along the horizon from the east or west point.

Apex of the sun's way—A point in the heavens towards which the whole solar system is moving; it is in Hercules.

Aphelion is the place of a planet's orbit when farthest from the sun.

Apogee, the point in the moon's or a planet's orbit which is farthest from the earth.

Apsis, plural apsides, the farthest and the nearest point from the attracting body in an elliptical orbit. The line joining these points is called the line of apsides.

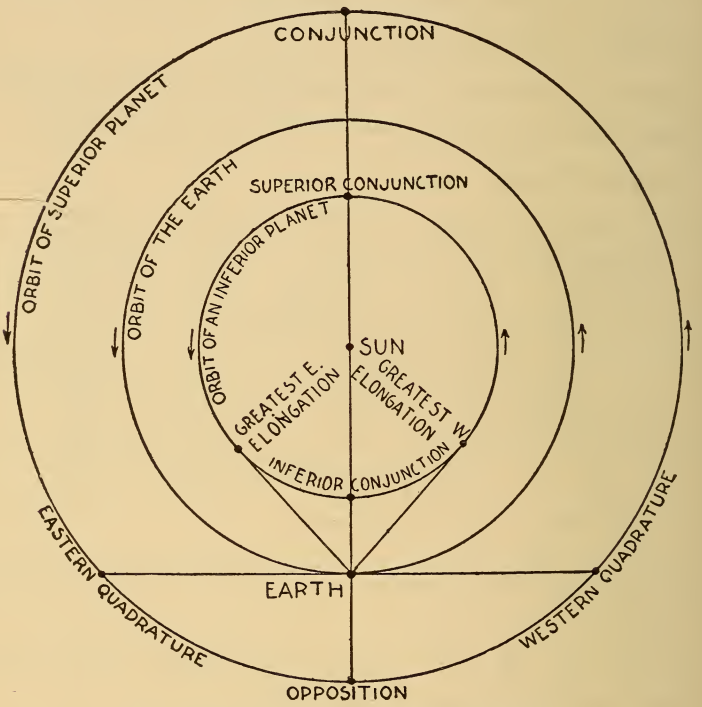

FIG. 33—ASPECTS OF THE PLANETS.

Aspects of a planet, its positions with reference to the sun as viewed from the earth. The principal aspects are: Conjunction, ☌, when the planet appears close to the sun; opposition, ☍, when the planet is in opposite direction from the sun and comes to the

meridian at midnight; quadrature, □, when the planet, earth and sun make a right angle at the earth. (See Fig. 33.)

Asteroids. See chapter XII.

Axis, the line around which a body rotates.

Azimuth, of a celestial body is the angular distance measured along the horizon from the north or south points to the vertical circle which passes through the celestial body.

Binaries are double stars which revolve around a common centre of gravity.

Bode's Law—An empirical rule for finding the approximate distances of the planets from the sun.

Celestial Latitude is the angular distance of a heavenly body from the ecliptic. There it nothing to correspond to it on the terrestial globe.

Celestial Longitude is the distance of a heavenly body measured from the vernal equinox along the ecliptic to the circle which passes through the object and is perpendicular to the ecliptic.

Clusters. See Chapter XXIX.

Colures are the four principal meridians of the celestial sphere which pass from the poles, one through each equinox, and one through each solstice.

Comets. See Chapter XIX.

Conjunction. See aspects.

Culmination, the passage of a heavenly body across the meridian.

Day Astronomical, commences at mean noon at any one place and is counted up to 24 hours; thus Feb. 3d, 11 a. m., is Feb. 2d. 23 hrs. of the astronomical day.

Day Sidereal is the time between two successive transits of the vernal equinox across the meridian. The sidereal day is about 4 minutes shorter than the ordinary day, sidereal noon therefore comes progressively earlier from day to day gaining exactly one day in one year.

Declination is the angular distance of a celestial body north or south of the celestial equator.

Direct Motion is motion among the stars from west to east.

Disc is the visible surface of the sun, moon or planets.

Eclipses. See Chapter IX.

Ecliptic, the apparent annual path of the sun among the stars.

Elements of an Orbit, the mathematical quanities necessary to compute the position and motion of a comet, planet or satellite.

Elongation is the angular distance of a planet from the sun as seen from the earth.

Equator, Celestial, the great circle in which the plane of the earth's equator produced cuts the celestial sphere.

Equinoctial, the celestial equator.

Equinoxes are the two points where the ecliptic cuts the equator; when the sun is at these points day and night are equal the world over; the sun is at the vernal equinox about March 20th and at the autumnal equinox about September 22d.

Faculae are brilliant, white patches on the sun's disc; they generally surround the sunspots and are best seen near the sun's limb.

Galaxy, or Milky Way. See Chapter XXIX.

Geocentric Position, the place of a heavenly body with reference to the earth's center.

Gibbous, that appearance of the moon or an inferior planet between full and half full phases.

Heliocentric Position, the place of a heavenly body with reference to the sun's center.

Horizon, Visible, the skyline.

Horizon Rational, or simply horizon, a great circle of the heavens whose plane is perpendicular to the observer's plumbline, and passes through the center of the earth, its poles are the zenith and the nadir.

Hour Angle is the angle made at the pole between the meridian and the arc of a great circle passing through the pole and the sun, satellite, planet, or star.

Inclination of an orbit is the angle between its plane and the plane of the ecliptic.

Inferior Conjunction, when an inferior planet is between the earth and the sun. See *Aspects.*

Inferior Planets, Venus and Mercury.

Intercalary Day, the extra day in a leap year.

Julian Calendar, the reckoning of time set up by Julius Caesar which ordains that every fourth year shall be a leap year.

Julian Day, a method of numbering days proposed by Joseph Scaliger in 1582; it is much used by astronomers; Jan. 1, 1906, is the 2,417,212th day of the Julian Period.

Julian Epoch, Jan. 1, 4,713 B. C., the date of commencement of the Julian Period.

Julian Period, consists of 7,980, (28x19x15,) Julian years of 365¼ days each; the year 1906 is the year 6619 of the Julian Period.

Leap Year, all years divisible by four, except the century years which must be divisible by 400.

Librations of the Moon, are apparent slight pendulous motions of the moon due to several causes; on account of libration considerably more than half of the moon's surface (59 per cent.) is visible, the remaining 41 per cent. never coming into view.

Limb, the edge of the disk of the sun, moon, or a planet.

Magnitudes of stars are their different degrees of brightness; the brighter the star, the smaller the number of the magnitude.

Mean Distance of a planet or a satellite is one half the major axis of its elliptical orbit.

Meridian of a place, a great circle passing through the zenith, the pole, and the north and south points of the horizon.

Meteorite, a body which falls from outer space towards the earth. See Chapter XX.

Nadir, the point in the celestial sphere directly beneath our feet, opposite to the zenith.

Nebula. See Chapter XXIX.

Nodes are two points where the orbit of a planet or of the moon intersect the plane of the ecliptic; ascending node, ☊, is the place where the body passes from south to north of the ecliptic; descending node, ☋, where the body passes from north to south of the ecliptic.

Occultation is the hiding of a star, satellite, or planet by the interposition of the moon or some other planet.

Opposition. See *Aspects.*

Orbit, the path of a planet, comet, or meteor around the sun, or of a satellite around a primary.

Parallax is the difference of direction of a heavenly body as seen from two points, as the centre of the earth and some points of its surface, or from two different points in the earth's orbit.

Penumbra, the partial shadow between the umbra, or region of total eclipse, and the exterior region of no eclipse; the half dark parts of a sunspot.

Perigee, the point in the moon's or a planet's orbit which is nearest to the earth.

Perihelion is the place of a planet's orbit when nearest to the sun.

Period, the time of revolution of a heavenly body about its primary.

Periodic, recurring or returning at regular intervals.

Perturbation is the effect of the attractions of the planets or other bodies upon each other which disturb their regular motion and distort their orbits.

Phases, the various appearances of the illuminated portion of the moon or of the interior planets.

Planets, the large bodies that revolve around the sun in elliptical orbits.

Planetoids are asteroids; see Chapter XII.

Poles Celestial, the two points on the celestial sphere, where the earth's axis of rotation produced pierces the celestial sphere.

Precession of the equinoxes, a slow shifting from east to west of the equinoxes; it amounts to a little more than 50″ a year.

Quadrature, see Aspects.

Radiant, is that point in the heavens from which the shooting stars belonging to a meteoric shower seem to diverge. It is merely a point of perspective, just as the rails of a straight piece of track seem to converge in the distance.

Refraction is the bending of a ray of light as it passes through media of different densities. Refraction affecting the apparent place of a heavenly body is greatest near the horizon, making *e. g.*, the sun appear just above the horizon when it is still below it; refraction decreases rapidly as the angle of elevation increases and is zero at the zenith.

Retrograde Motion is an apparent motion of planets and satellites from east to west.

Revolution, the motion in a closed curve of the heavenly bodies around their centres of attracting force; a complete circuit of such a motion.

Right Ascension is the angular distance measured eastward along the equator from the vernal equinox to the arc of a great circle which passes through the poles and the heavenly body; it is generally expressed in units of time. See Problem II, Appendix I.

Rotation is the motion of a body around its axis.

Satellites are moons revolving around the planets.

Sidereal Year is the time required by the sun to move once around the ecliptic from any fixed star to the same star again. The sidereal year is longer than the tropical year by about 20 minutes.

Signs of the Zodiac, are the twelve equal parts of 30° each into which the zodiac is divided, they are: Aries ♈, Taurus ♉, Gemini ♊, Cancer ♋, Leo ♌, Virgo ♍, Libra ♎, Scorpio ♏, Sagittarius ♐, Capricornus ♑, Aquarius ♒, Pisces ♓. Formerly the signs and the constellations coincided; on account of the precession of the equinox, however the sign of Aries has backed into the constellation Pisces, the sign of Taurus into the constellation Aries, and in like manner the remaining signs.

Solstices are the two points in the ecliptic which are most distant from the equator. The sun passes the

summer solstice about June 21st and the winter solstice about December 21st, giving the sun the longest and the shortest path above the horizon, respectively.

Superior Planets are the planets which are farther from the sun than the earth.

Synodic Period of a planet is the time required by a planet to pass from opposition to opposition or from inferior conjunction to inferior conjunction again.

Syzygies are points of new and full moon of the moon's orbit; they also denote the points of a planet's opposition or conjunction.

Terminator, the dividing line between the illuminated and the dark part of the moon's or a planet's surface.

Transit, the passage of a celestial body across the meridian; also the passage of Venus or Mercury across the sun's disc or of a satellite across the disc of its primary.

Tropical Year is the time required by the sun to pass from the vernal equinox to the vernal equinox again.

Umbra, that part in an eclipse where the direct light is entirely cut off; the darkest part in a sunspot.

Vertical Circles pass through the zenith and are perpendicular to the horizon; the prime vertical is

the circle passing through the zenith and the east and west points.

Zenith is the point overhead in the celestial sphere.

Zodiac is a belt 18° wide encircling the heavens, the ecliptic lying along the middle of this belt; the planets always remain within this belt.

Zodiacal Light, see Chapter XXI.